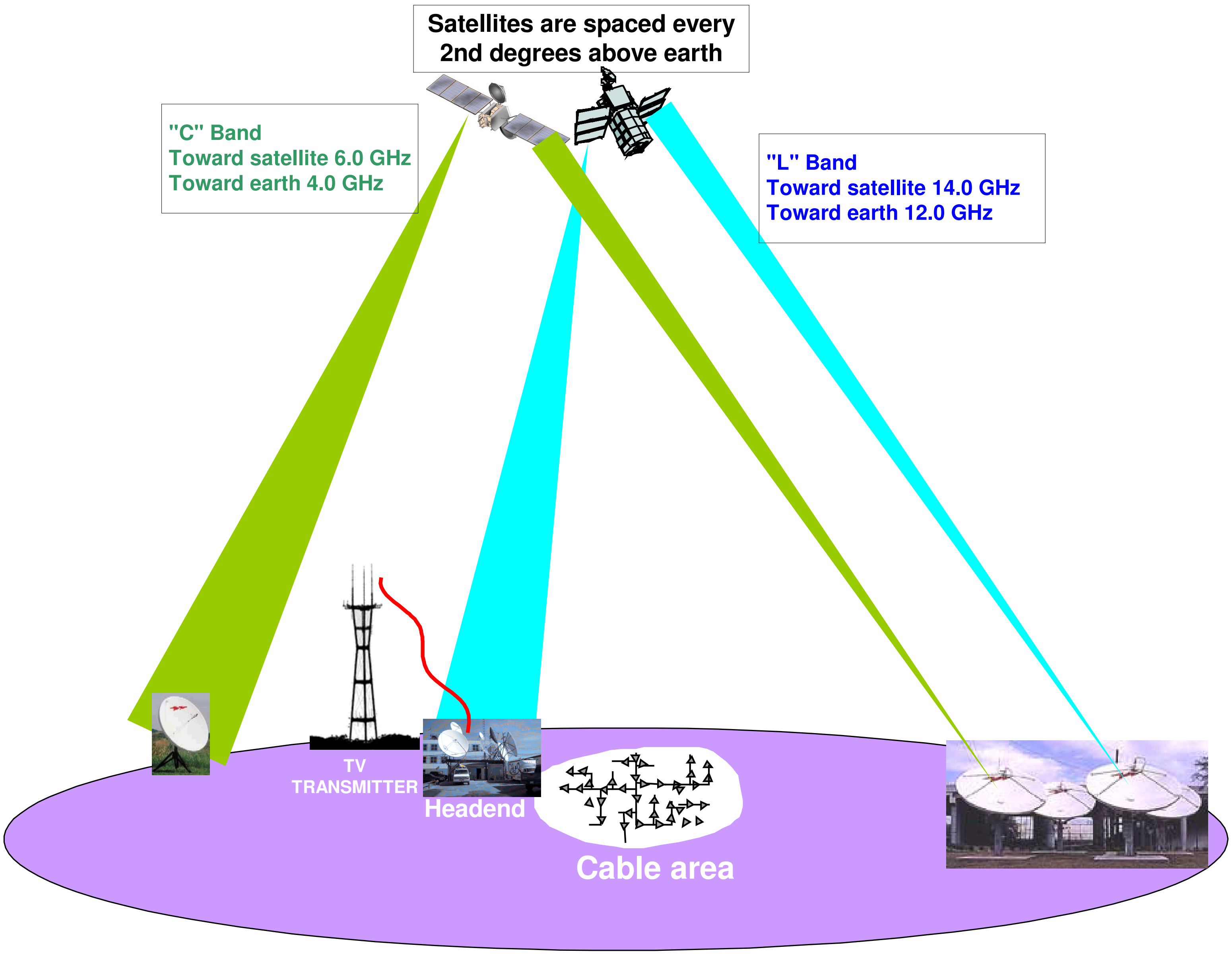
# Broadband System - D




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Coaxial Cable and Fiber Optic.

# Coaxial Cable.

- Coaxial cable gives the possibility of transporting electrical signal, like Television signal and other types of signal.
- CATV, Coaxial cable frequency's response is from; 5 to 1000 MHz.
- Coaxial cable is also capable of transporting 60 or 90 Volts AC, needed to activate RF amplifier and other type of active equipment.
- Coaxial cable has a 75 ohms impedance +/- 2 ohms.
- VSWR (Structural Return Loss) is 37 dB and better.

- The Construction of the Coaxial cable consist of:
- An aluminium tube, sometime covered with a PVC protecting sheath.
- A centre conductor (solid cooper or cooper clad)
- The central conductor is held in place by foam.
- There are (2) Two types of coaxial cable been produced;
- **P-III,** an aluminium tube, squeeze around the foam and the centre conductor.
- **QR,** a flat aluminium plate, rounded and solder around the foam.

# Coaxial Cable.

HFC System bandwidths are increasing to 750 MHz and 1 GHz.  As the CATV industry moves forward, we must be continually looking out for better ways of doing things. This is the case with cable measurements as we push the frequency range up to 1 GHz. To meet these need coaxial cable must  meet the following;

- **Insertion Loss to 1 GHz.**

The insertion loss or attenuation of the cable describes how signal loses energy as it travels through the cable. The loss is usually described in terms of a power ratio in dB and it increases with the signal frequency. For coaxial cables these losses are attributed to the conductor and the dielectric. The electrical properties of these materials are well known; thus the insertion loss is predictable from DC to 1 GHz.

- **Impedance.**

The cable characteristic impedance is the ration of the voltage to current for a wave traveling in the cable. Ideally coaxial cable impedance appears purely resistive across the frequency band and CATV coaxial cables are designated to have 75 ohm impedance, the standard used by CATV industry. 75 ohms is nearly the optimum impedance for the lowest attenuation. For higher frequencies, greater than 5 MHz, the coaxial impedance is related to the ration of the inner conductor dimensions and the dielectric between them. Unfortunately, the cable impedance is not exactly 75 ohms across the frequency band and is generally within +/- 2 ohms from 75 for trunk and feeder cable and within +/- 3 ohms for drop cable.

# Coaxial Cable.

•**Return Loss.**

When the cable impedance is not exactly 75 ohms, there will be an impedance mismatch and a reflection of energy if it is connected to an ideal 75 ohms signal source. This reflection can be quantified in terms of the return loss:

$$RL = 20\ LOG \left[ \frac{Z_{DEVICE} - Z_0}{Z_{DEVICE} + Z_0} \right]$$

Where $Z_{DEVICE}$ is the complex characteristic impedance of the device (ohms) and $Z_0$ is 75 ohms for CATV system.

Since the cable impedance is within a few ohms of 75, the return loss, as opposed to the cable's structural return loss, is very good and usually better then 37 dB. The structural return loss, which deals with return loss at particular frequencies, will be discussed next.

# Coaxial Cable.

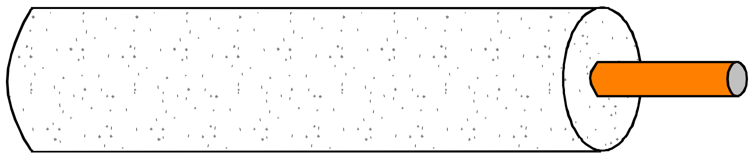
•**Structural Return Loss.**

As coaxial cable is manufactured, a number of variables can cause the impedance to change. Recall, the cable's impedance is a function of the cable's physical properties (conductor diameters, insulation's dielectric constant) and if any of these properties change, the impedance will change. For example, the dielectric material is extruded over the centre conductor during manufacturing process. As the dielectric is extruded, its diameter or dielectric constant can change and cause the impedance to change. This impedance change is extremely small and difficult to measure. If only one of these impedance changes occurs in the cable or if they occur at random intervals, the return loss will be good; but due to manufacturing processes, there may be many evenly spaced impedance changes and return loss problem will arise. Reflection from these evenly spaced impedance changes add together at a frequency corresponding to a half wavelength spacing. Although, each impedance change may be very small, when they all add together, they cause a return loss "spike". These spikes can be narrower than 200 KHz. The return loss from these impedance changes is called the structural return loss because the impedance variations are due to structural no uniformities in the cable. The challenge for measuring cable to 1 GHz is complicated and the test equipment must have extended bandwidth (greater than 600 MHz) without sacrificing the ability to resolve and accurately measure these sharp SRL spikes.

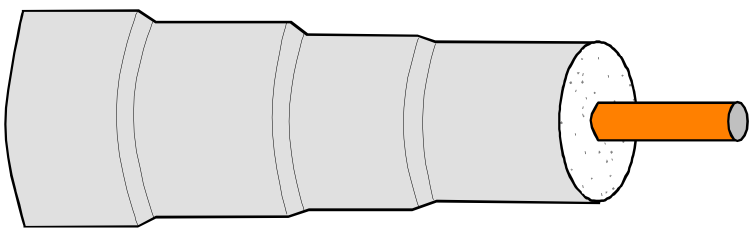
# P – III - Coaxial Cable.



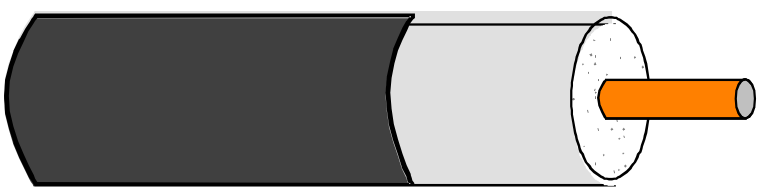
Central conductor.



Central conductor and foam.



Coaxial Cable been press into final product.



Final product covert with PCV.

## P-III- Coaxial cable is made with the following steps;

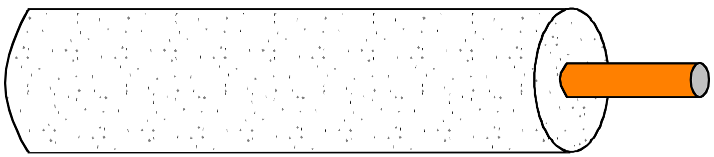
1. Centre conductor is spray with glue so it will stay in position when covert with foam.
2. The centre conductor is then covert with foam, which is then also spray with glue.
3. The foam and the centre conductor are then installed in a aluminium tube.
4. The aluminium tube is then compressed three time to make the final coaxial cable.
5. When needed, the coaxial cable can be covert with PVC jacket. This jacket will protect the aluminium from been damaged by the environnement.

# QR - Coaxial Cable.

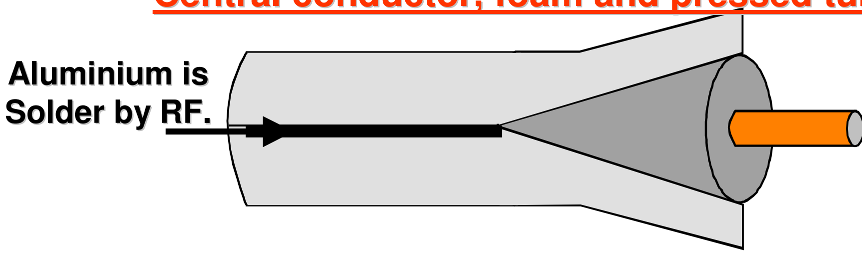
Central conductor.



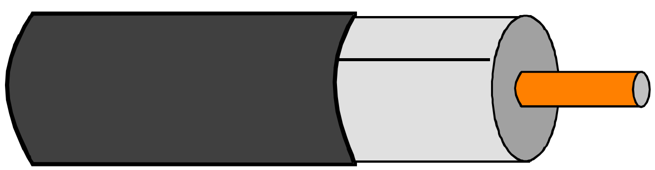
Central conductor and foam.



Central conductor, foam and pressed tube.




Final product covert with PCV.



## QR - Coaxial cable is made with the following steps;

1. Centre conductor is spray with glue so it will stay in position when covert with foam.
2. The centre conductor is then covert with foam, which is then spray with glue.
3. An aluminium Flat plate is then roll and compressed around the foam. This aluminium plate once wrapped around the foam is welded together by an RF soldering.
4. When needed the coaxial cable can be covert with PVC jacket, this will keep the aluminium tube away from been damage by the environnement.

# Coaxial Cable.

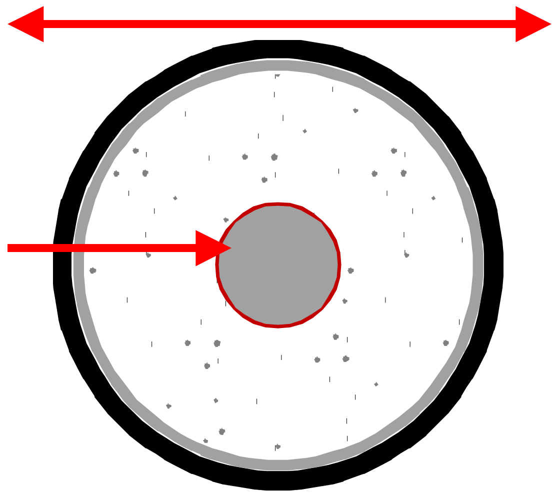
**In General coaxial cable has the following electrical characteristic;**

- 75 OHMS impedance +/- 2 ohms.
- Velocity of propagation 89% minimal.
- Capacitance of 15.2 pF/Ft. or 49.9 pFMt.
- Frequency response between 5 to 1000 MHz, depending on the type.
- DC resistance at 68 degrees F. (20 C.) in OHMS per 1000 Ft. or Mt.

# P – III - Coaxial Cable Dimensions.

P - III - 1000”
P - III - 875”
P - III - 750”
P - III - 625”
P - III - 500”
P - III - 412”

The center conductor will have a different diameter depending on the size of the cable





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# P – III - Coaxial Cable Signal Loss.

**Signal loss.**

| | 5 | 30 | 50 | 300 | 550 | 750 | 870 | 1000 | MHz |
|---|---|---|---|---|---|---|---|---|---|
| *P-III-500* | 0.16 | 0.39 | 0.50 | 1.28 | 1.77 | 2.10 | 2.33 | 2.53 | *dB-100'* |
| *P-III-625* | 0.12 | 0.31 | 0.40 | 1.04 | 1.45 | 1.72 | 1.94 | 2.11 | *dB-100'* |
| *P-III-750* | 0.10 | 0.26 | 0.34 | 0.86 | 1.20 | 1.43 | 1.60 | 1.74 | *dB-100'* |
| *P-III-875* | 0.09 | 0.22 | 0.28 | 0.74 | 1.03 | 1.23 | 1.40 | 1.53 | *dB-100'* |
| *P-III-1000* | 0.08 | 0.20 | 0.26 | 0.68 | 0.96 | 1.16 | 1.32 | 1.44 | *dB-100'* |

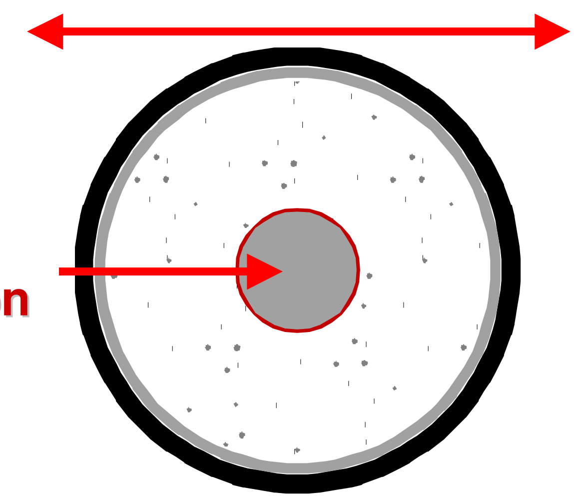
**DC Resistance Cooper-Clad center**

| | | | | |
|---|---|---|---|---|
| *P-III-500* | 1.70 | 1000' | 5.58 | 1000mt |
| *P-III-625* | 1.09 | " | 3.58 | " |
| *P-III-750* | 0.75 | " | 2.46 | " |
| *P-III-875* | 0.55 | " | 1.80 | " |
| *P-III-1000* | 0.41 | " | 1.35 | " |

**Above at 68º F (20º C)**

## QR - Coaxial Cable Dimensions.

QR - 1125”
QR - 860”
QR - 715”
QR - 540”



The center conductor will have a different diameter depending on the size of the cable



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# QR - Coaxial Cable Signal Loss.

## Signal loss.

| | 5 | 30 | 50 | 300 | 550 | 750 | 870 | 1000 | MHz |
|---|---|---|---|---|---|---|---|---|---|
| QR-540 | 0.14 | 0.34 | 0.44 | 1.13 | 1.56 | 1.85 | 2.00 | 2.17 | *dB-100'* |
| QR-715 | 0.11 | 0.27 | 0.35 | 0.89 | 1.26 | 1.49 | 1.62 | 1.75 | *dB-100'* |
| QR-860 | 0.09 | 0.23 | 0.30 | 0.76 | 1.06 | 1.24 | 1.33 | 1.44 | *dB-100'* |
| QR-1125 | 0.07 | 0.17 | 0.22 | 0.50 | 0.84 | 1.01 | 1.11 | 1.20 | *dB-100'* |

## DC Resistance Cooper-Clad center

| | | | | |
|---|---|---|---|---|
| QR-540 | 1.61 | *1000'* | 5.28 | *1000mt* |
| QR-715 | 0.997 | *"* | 3.27 | *"* |
| QR-860 | 0.724 | *"* | 2.38 | *"* |
| QR-1125 | 0.420 | *"* | 1.38 | *"* |

Above at 68º F (20º C)

# Coaxial Cable Behaviour with Temperature.

The changes in temperature will affect the transmission of the electron (frequency) inside a coaxial cable. The hotter it gets inside the cable the harder it is for the electron to circulates, causing a higher loss in dB at all frequencies. If the inside of the cable get cold, this will permit the electrons to circulates easier, causing less loss.

Since the loss of all coaxial cables are giving at; 68 degrees F. or 20 degrees C. There will be an increase or a decreased in loss specification of all coaxial cable when the temperature changes. For every degrees F. changes at any frequency, starting from 68.0 degrees F. there will be a loss or a gain of 0.0011% per feet. For the Celsius temperature, there will be an add or extra loss of 0.002% per meter.

Formula:

Att at 68 F { 1+0.001 (t-68)}

Att at 20 C { 1+0.002 (t-20)”

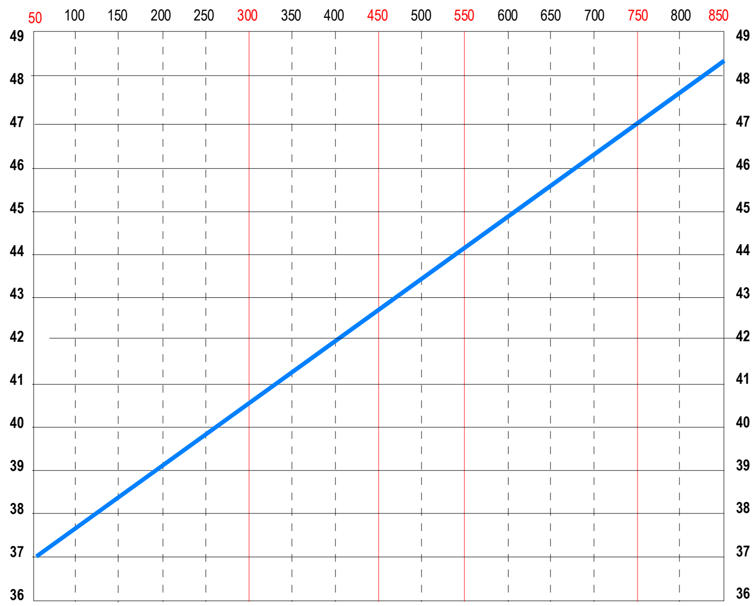
Example: Calculate the loss at –20 F of 20 dB of cable:

Att 20 F {1+.0011 (-20 – 68)} = 18.06 dB

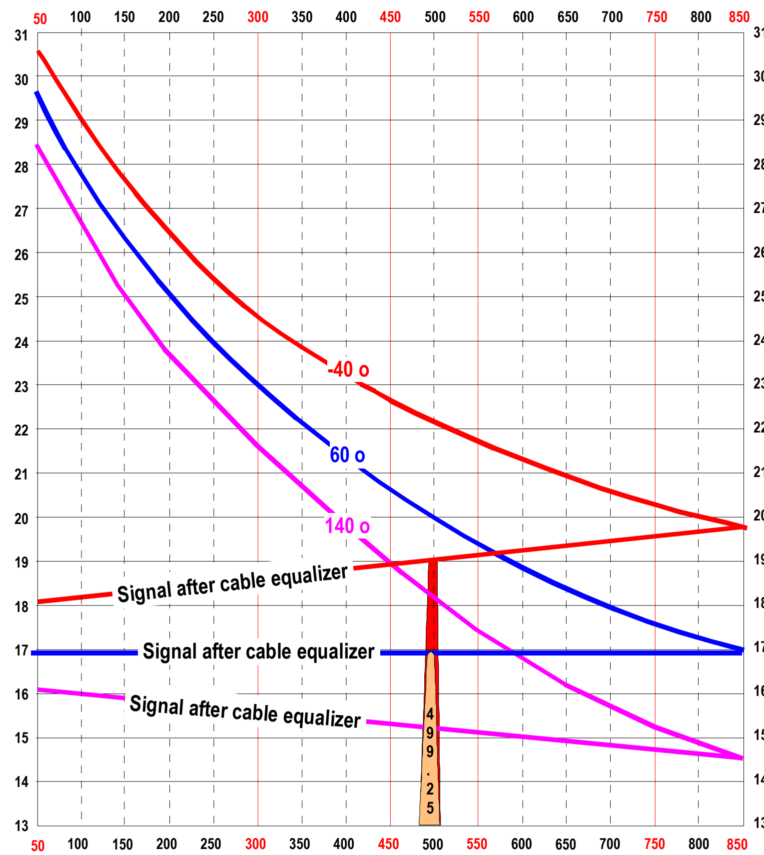
# Coaxial Cable Behaviour with Temperature.

**Coaxial cable technical characteristics changed with temperature. The cable stay the same length, but will act as it has lost couple of hundred feet, when the temperature get cold and it will do the opposite during warm weather.**

**Output previous amplifier**




**Input next amplifier after 30 dB spacing at 870 MHz**

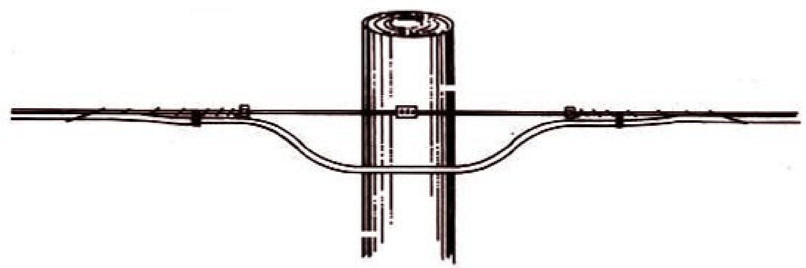


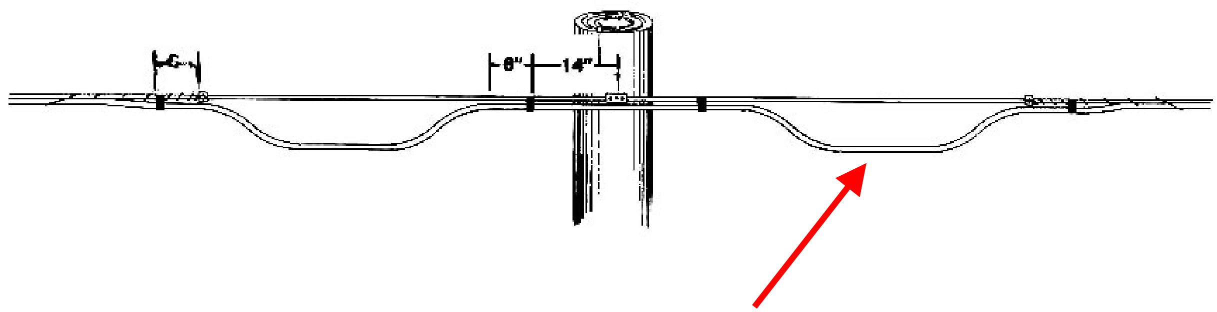



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## Coaxial Cable Behaviour with Temperature.

One more problem with coaxial cable and temperature changes, is the moving of the cable while been supported by the strand. Coaxial cable will required expansion loops at each pole to minimized this movement, weather there is equipment or not at each pole location.





## Coaxial Cable and distance between Amplifiers.

To calculate the distance between amplifiers, you need to know the following;

- Maximum frequency of the system in MHz.
- Type of cable to be utilised, size and type.
- The loss in dB per feet of the cable at maximum frequency of the system.
- Operating gain of the amplifier, at the maximum frequency of the system.

Calculating the spacing between two (2) amplifiers;

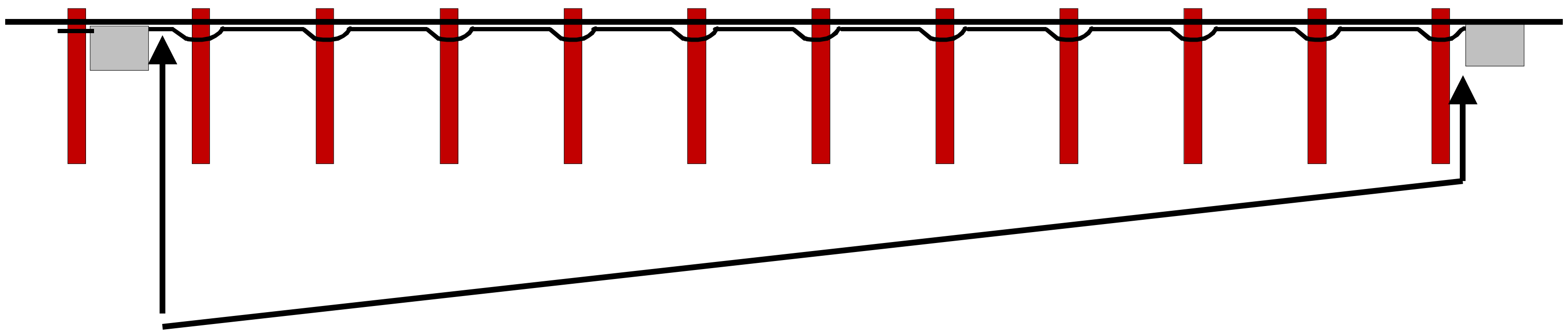
- Frequency 870 MHz.
- Cable T-10 / 625.
- Loss of cable at 870 MHz;  1.95 dB per 100 feet or 6.4 dB per 100 meter.
- Operating gain of amplifier; 36 dB at 870 MHz.

Distance calculation;

36 / 1.95 = 18.367 X 100 feet = 1,836.73 feet between amplifier.

36 / 6.40 = 5.625 X 100 metre = 562.5 metre between amplifier.

# Coaxial Cable and distance between Amplifiers.



**The spacing between the amplifier will depends on the maximum frequency of the system and the distance between the amplifiers.**

**Let say the spacing between these two amplifiers is 1,800 feet, and we are using P-III-625 cable.**

**A 450 MHz system, spacing will be : 24.30 dB spacing. (loss is 1.35 dB/100')**

**A 550 MHz system, spacing will be : 27.18 dB spacing. (loss is 1.51 dB/100')**

**A 750 MHz system, spacing will be : 32.22 dB spacing. (loss is 1.79 dB/100')**

**A 870 MHz system, spacing will be : 34.92 dB spacing. (loss is 1.95 dB/100')**

# Coaxial Cable and Equalizer Formulas.

## Cable Loss Ration

The ratio of cable attenuation at two frequencies is approximately equal to the square root of the ration of the two frequencies.

Example: What is the cable loss at 55 MHz when the loss is 20 dB at 450 MHz

$$\text{Cable Loss Ratio} = \sqrt{\frac{55}{450}} \quad 6.99\text{ dB}$$

Calculate the cable loss at 55 MHz when the loss at 450 MHz when the TILT is 12 dB between 55 and 450 MHz:

$$\text{dB of cable} \; \frac{12}{\sqrt{\frac{55}{450}}} = 18.45\text{ dB}$$

# Coaxial Cable and Equalizer Formulas.

## Tilt to Cable Loss

**To convert tilt (differential en signal level between end frequencies of the cable bandpass) to cable loss at higher frequency:**

$$\text{dB of Cable} = \frac{\text{Tilt(dB)}}{1 - \sqrt{\frac{f_1}{f_2}}}$$

**Calculate the cable loss at 870 MHz when the tilt is 26 dB between 55 and 870 MHz**

$$\text{dB of Cable} = \frac{26}{1 - \sqrt{\frac{55}{870}}} = 24.454 \text{ dB}$$



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# Coaxial Cable and DC current.

## Loop Resistance vs Temperature

Cable loop resistance is the draw in ohms of the coaxial cable. This draw is less with bigger cable and more with smaller cable.

It is generally given at 68 degrees F. or 20 degrees C.

| Cable : | 500 | 625 | 750 | 870 | 1000 |
|---|---|---|---|---|---|
| CA | 1.72 | 1.10 | 0.76 | 0.55 | 0.40 |
| SC | 1.20 | 0.79 | 0.56 | 0.41 | |

CA = Cooper Clad Aluminium Centre Conductor

SC = Solid Copper Centre Conductor

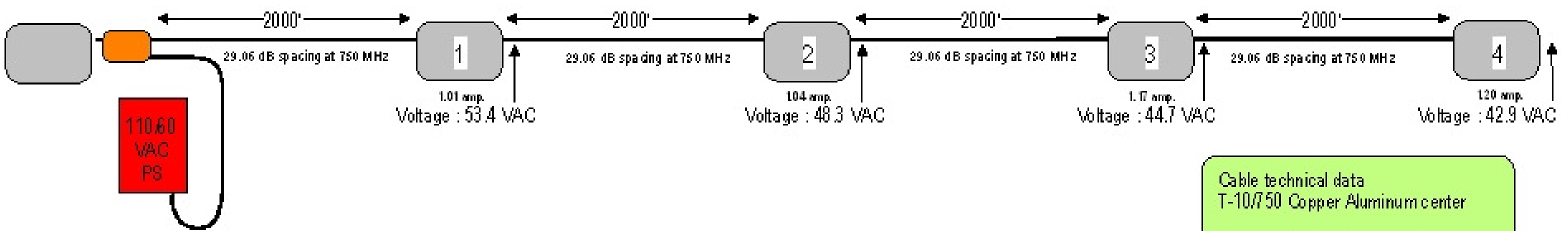
Calculate the loop resistance at 120° F when the resistance is 3.0 ohms at 68° degrees F.

R at 120° F. = 3 {1+.0022 (120 – 68 )} = 3.34 Ohms

# Coaxial Cable and DC current.

## *Example of two 750 MHz CATV system using T-10/750 versus QR-715 coaxial cable*

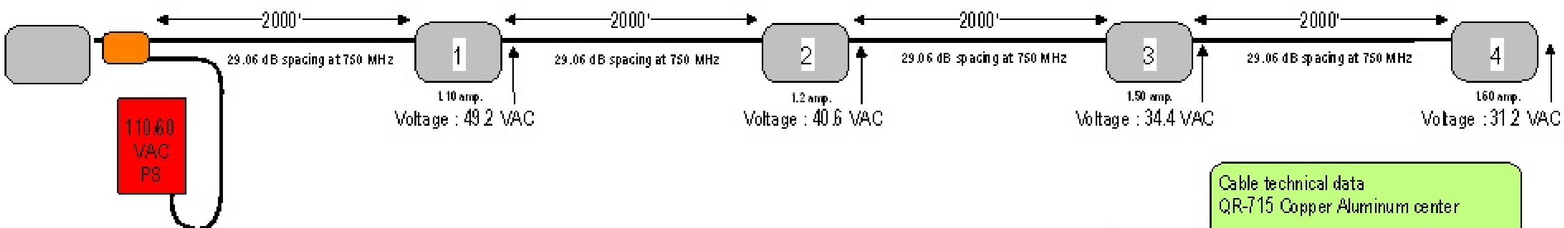
### System using T-10/750 coaxial cable




Cable technical data
T-10/750 Copper Aluminum center

Loss at 750 = 1.48 dB/1000'
Loop Resistance = 0.75 Ohms/1000'
at 68 degrees F.

### System using QR-715 coaxial cable




Cable technical data
QR-715 Copper Aluminum center

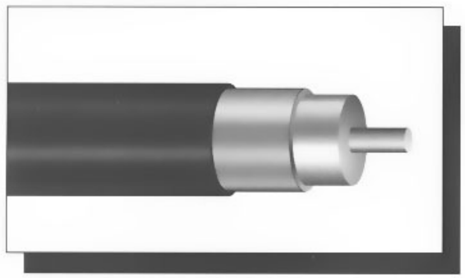
Loss at 750 = 1.50 dB/1000'
Loop Resistance = 0.997 Ohms/1000'
at 68 degrees F.

Amplifier spec. MB-865/15
Amp. current draw

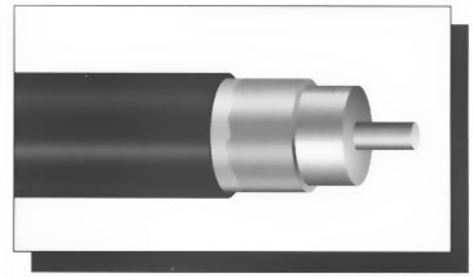
| VAC | Amp. |
|---|---|
| 90 | 0.62 |
| 75 | 0.71 |
| 60 | 0.86 |
| 53 | 1.01 |
| 45 | 1.15 |
| 38 | 1.41 |

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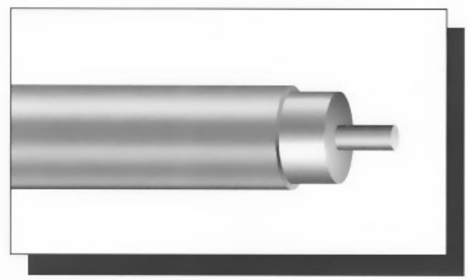
# Types of  Coaxial Cable.



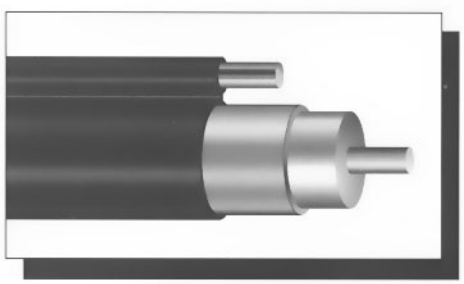
Jacketed



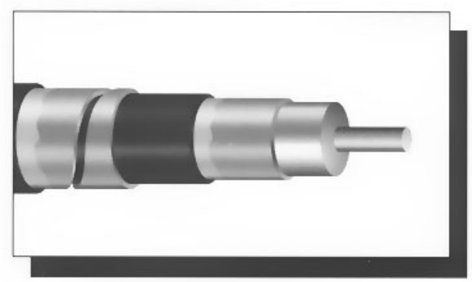
Jacketed Burial



Unjacketed

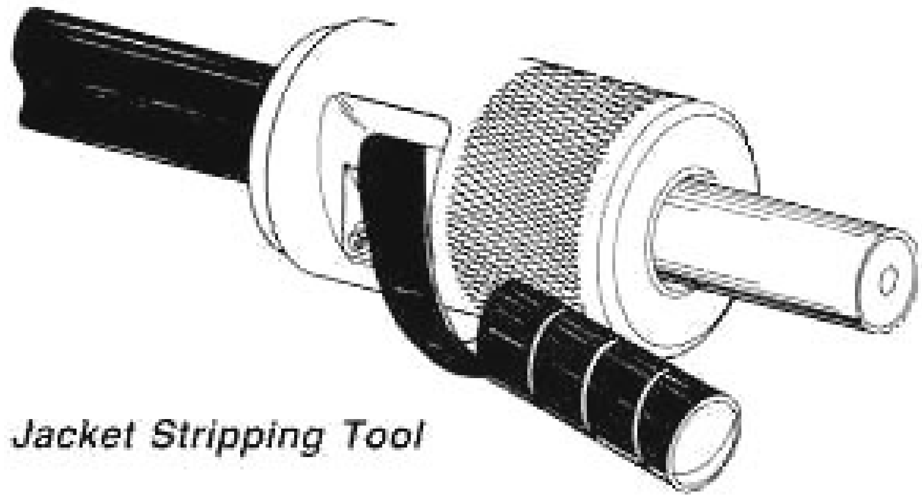


Messengered



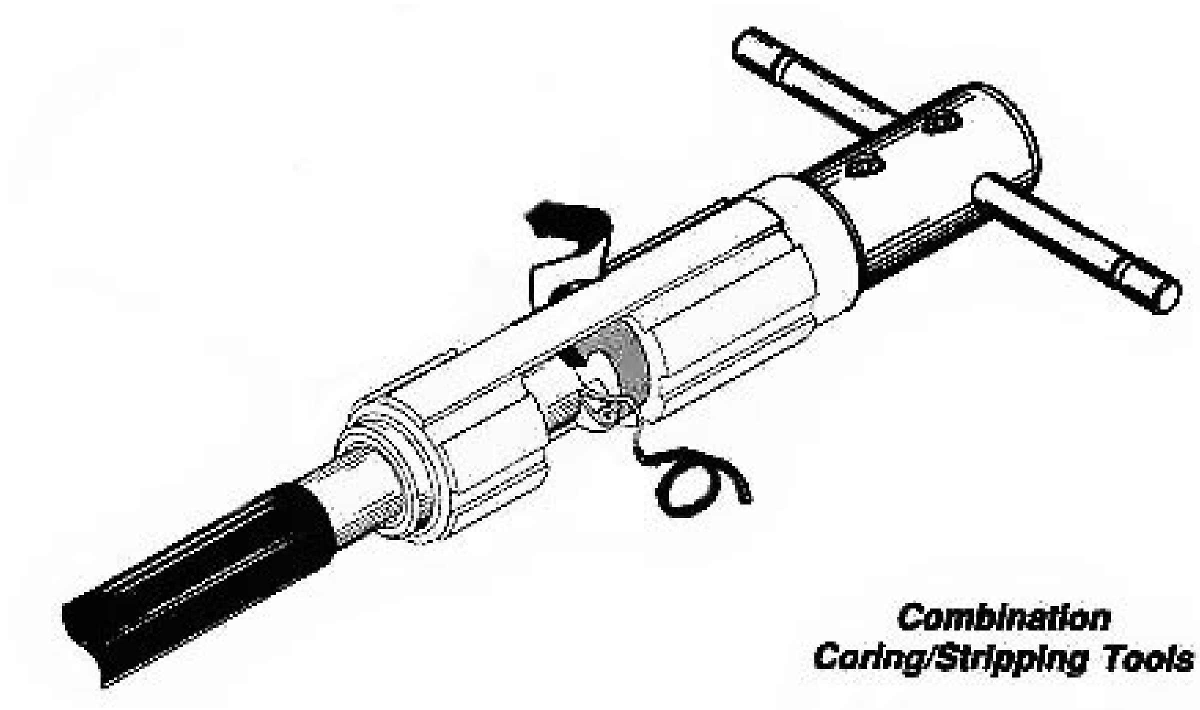
Armored

## Preparation of a Coaxial Cable Before the Installation of a Connector.



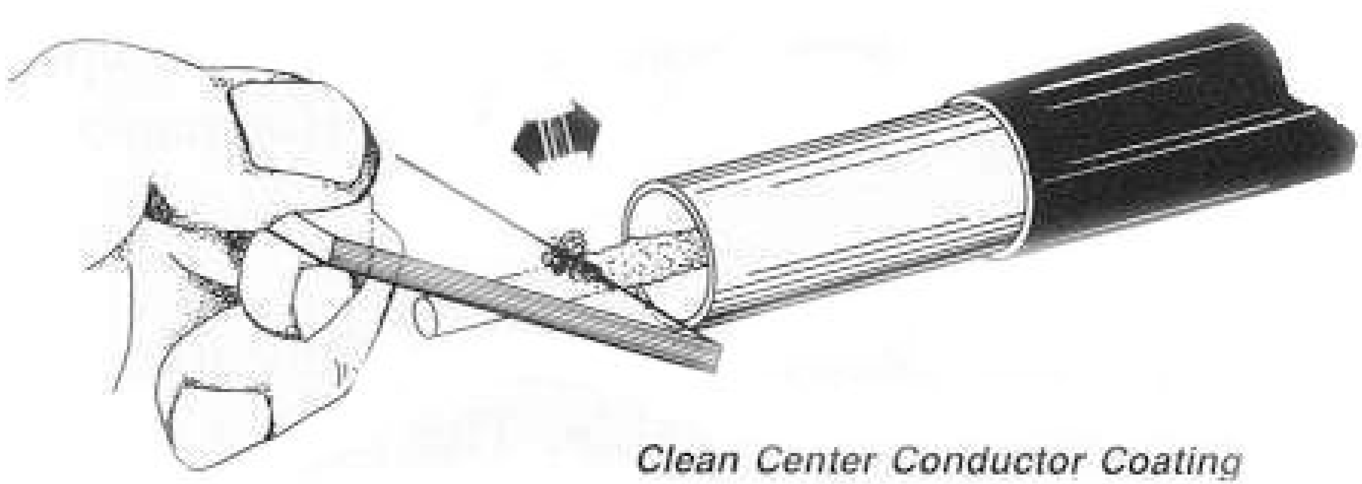

**The first operation, before installing a connector on coaxial cable, is to strip the PVC of the cable, if existing.**

## Preparation of a Coaxial Cable Before the Installation of a Connector.




**You then have to remove the foam between the centre conductor and the inside of the aluminium tube. This operation will permits the introduction of the ingress sleeve.**

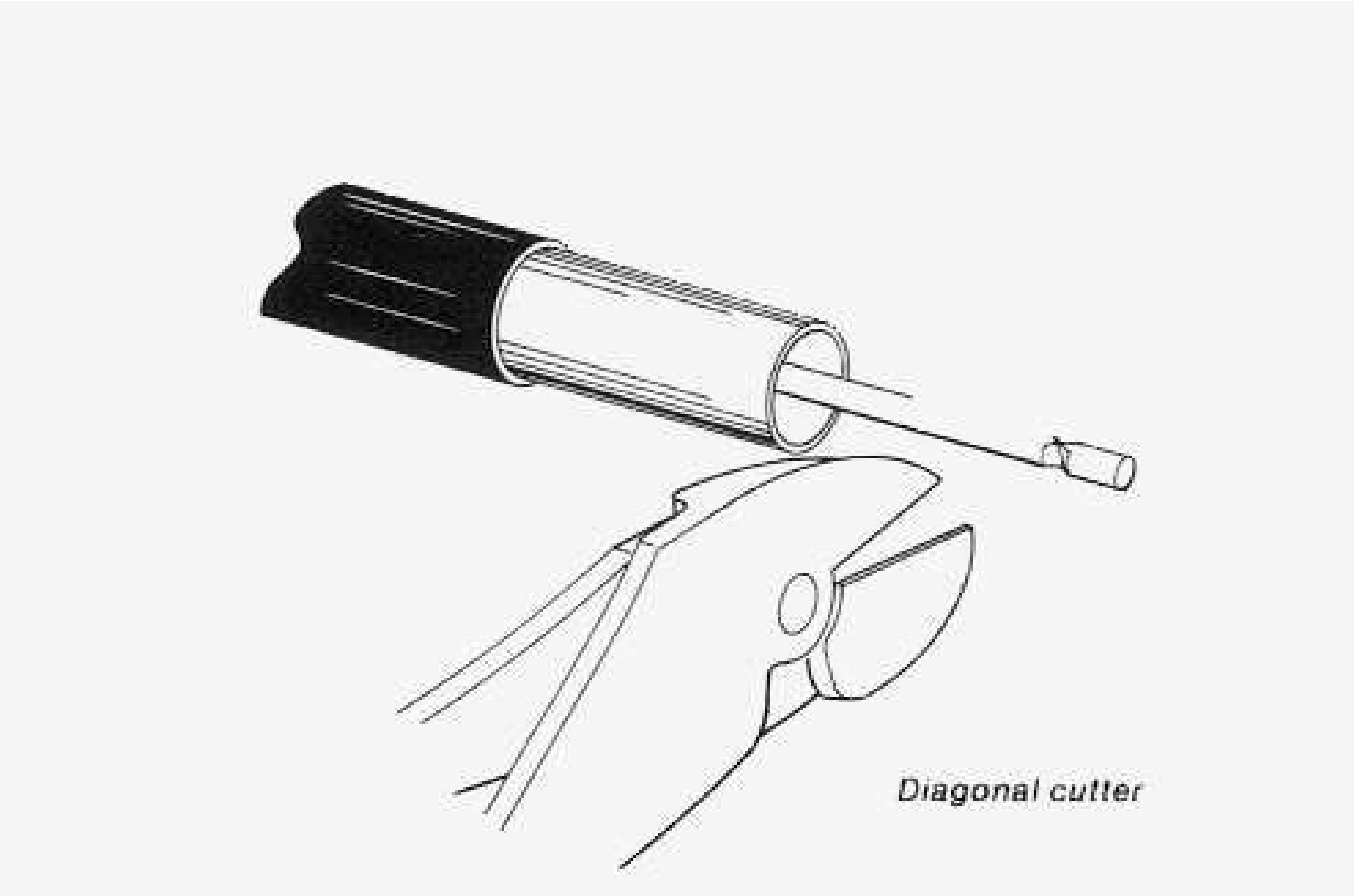
## Preparation of a Coaxial Cable Before the Installation of a Connector.




**You then have to remove the glue on the centre conductor, this will assure a good connection between the jaws of the connector and the centre conductor.**

**The removal of the glue should be done with a plastic object not to scratch the centre conductor.**

## Preparation of a Coaxial Cable Before the Installation of a Connector.

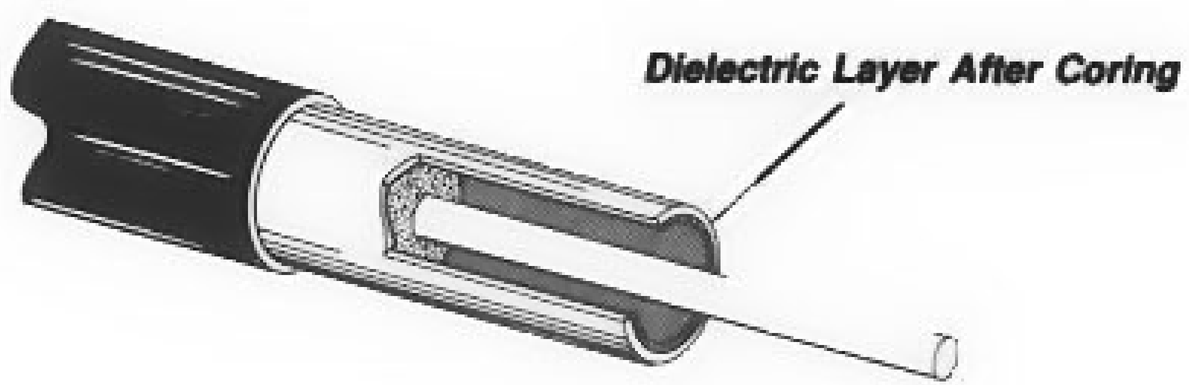



**You then need to cut the centre conductor to the length requires by the connector you are using.**



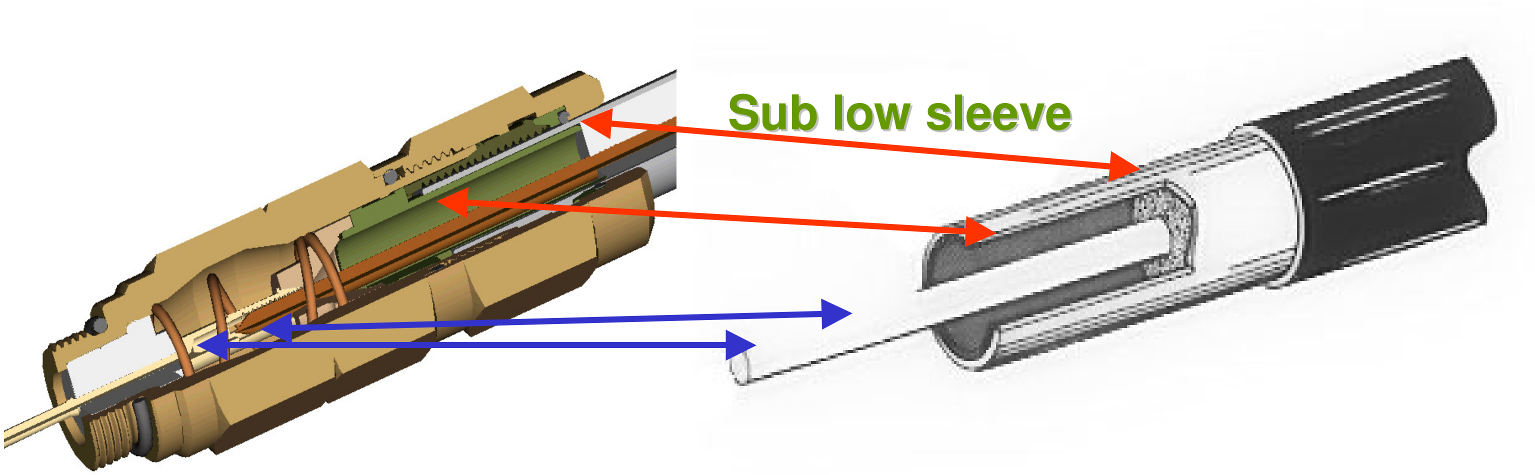
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## Preparation of a Coaxial Cable Before the Installation of a Connector.




**Completed preparation of the end of the coaxial cable, before the installation of the connector.**

# Proper Installation of the Connector.

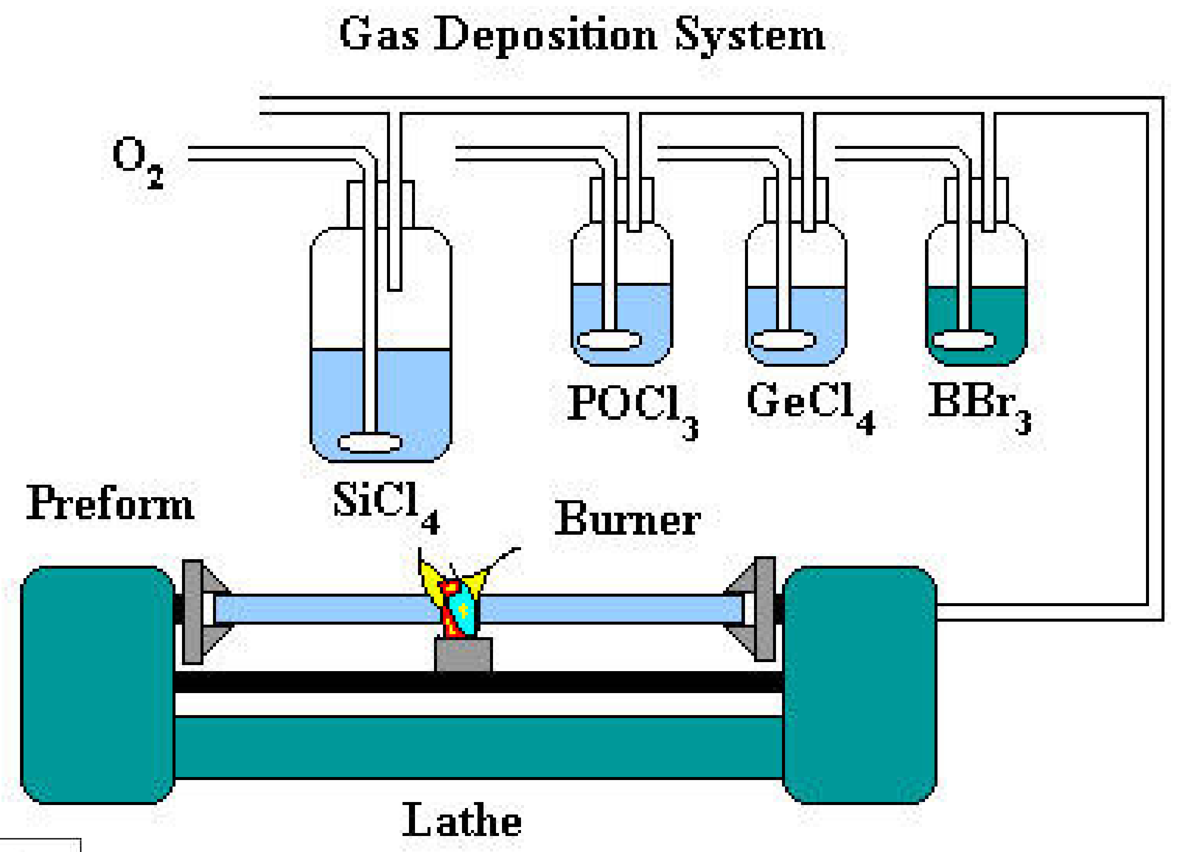



**Final installation of the connector equipped with sub-low sleeve.**

# Fiber Optic.

# How Fiber Optic is Made.

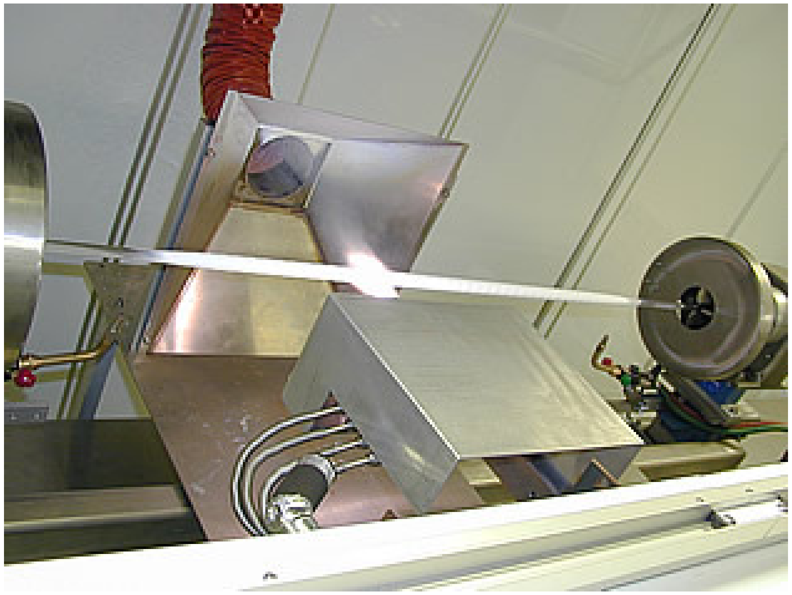
Fiber optic comes from a Preform made of silica, and other products. The first operation consist on building  a PREFORM, that will be melted into a solid center of 8.5 to 9.0 microns for singlemode fiber and in a solid center of 50.0 or 62.5 microns for multimode fiber.

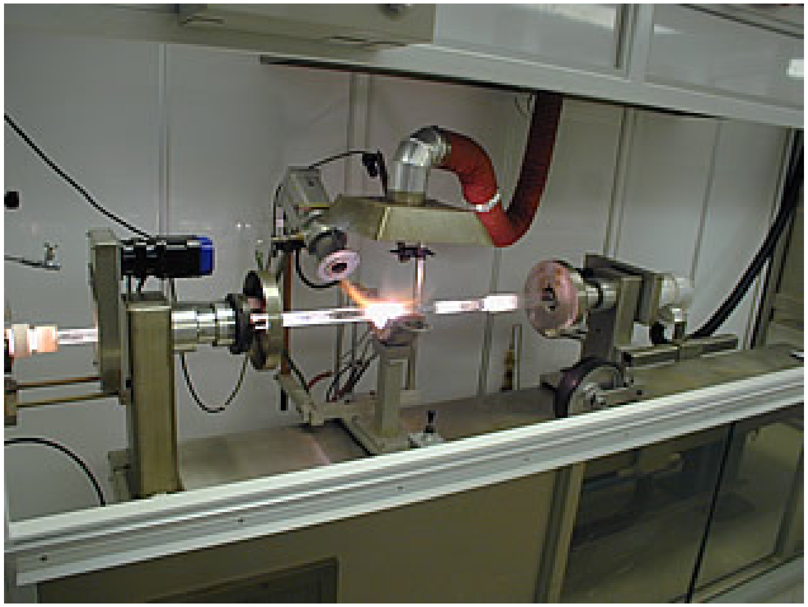





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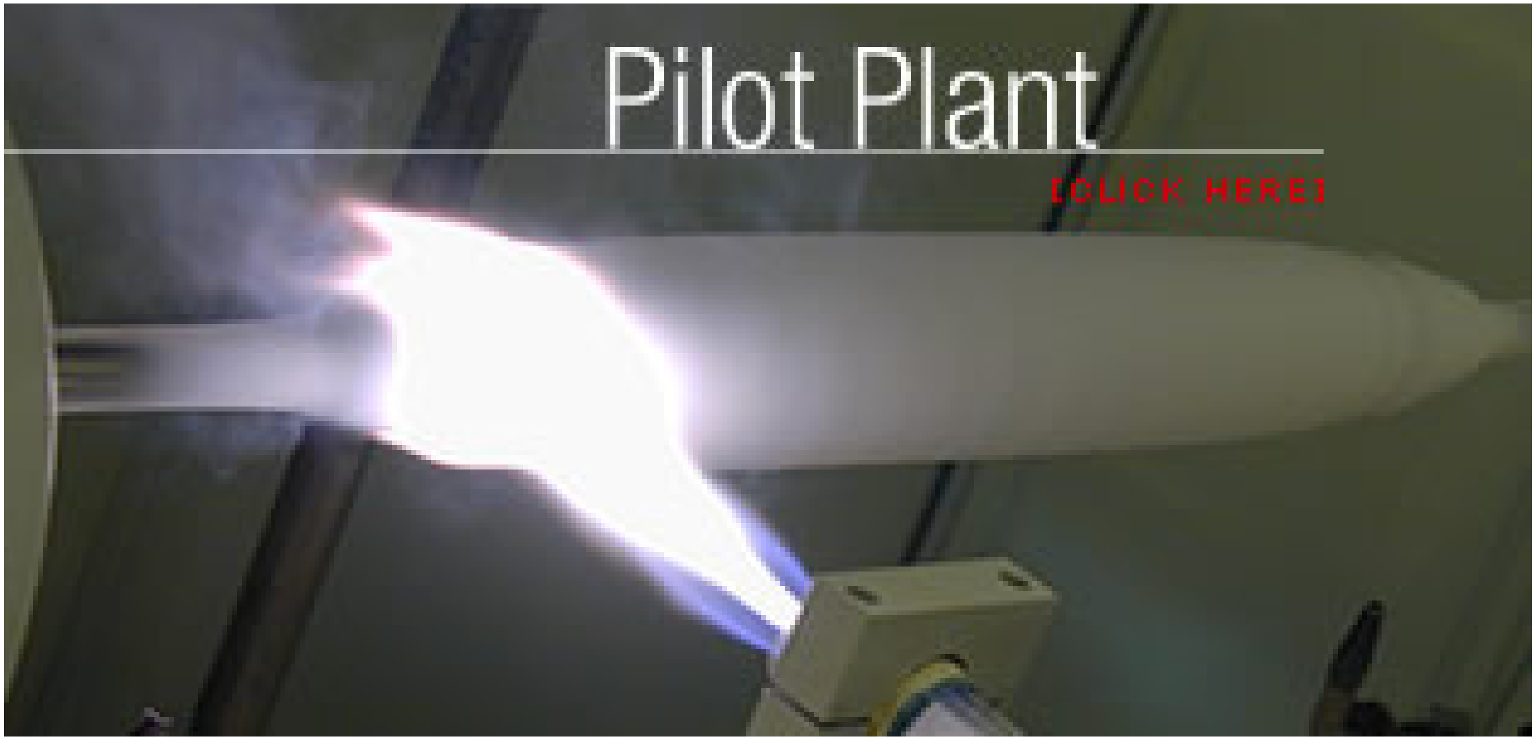
# How Fiber Optic is Made.





**A PREFORM been produced**

# How Fiber Optic is Made.



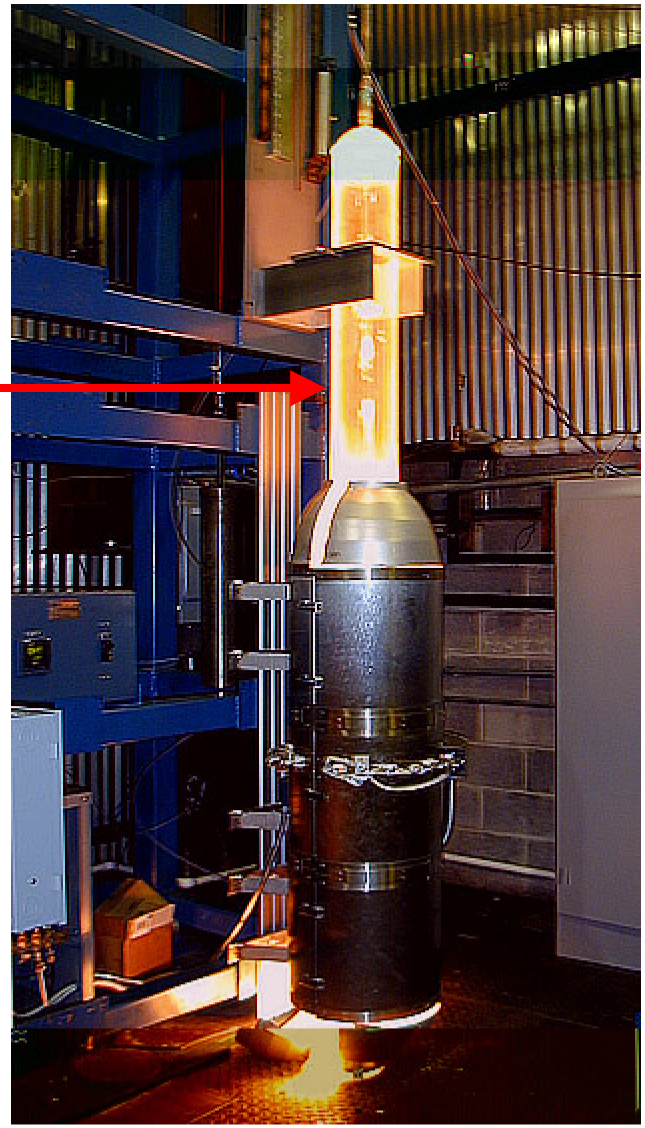

A PREFORM nearly completed.



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# How Fiber Optic is Made.

PREFORM





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# How Fiber Optic is Made.

Draw Tower

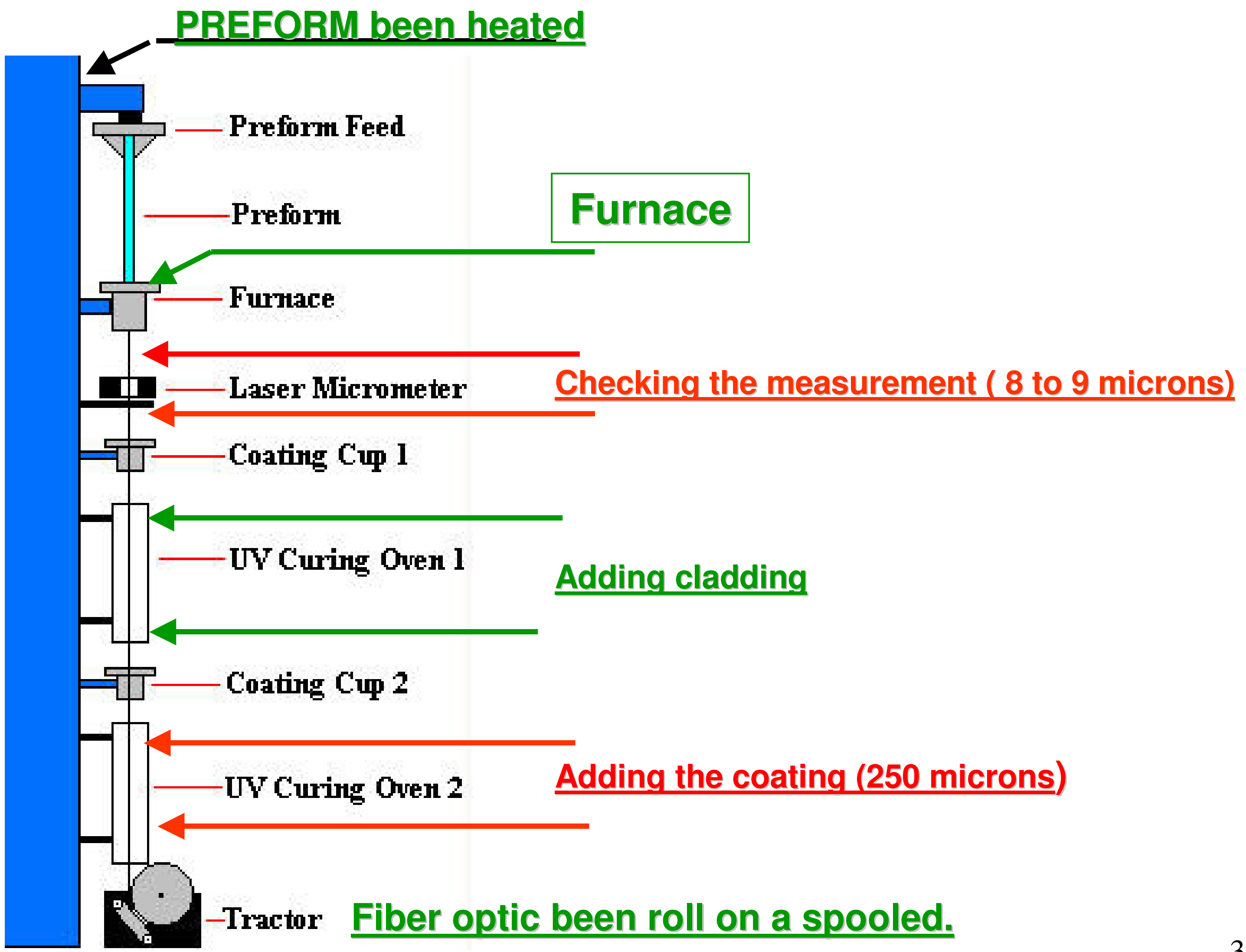


Final fiber optic before colour coding Is been applied



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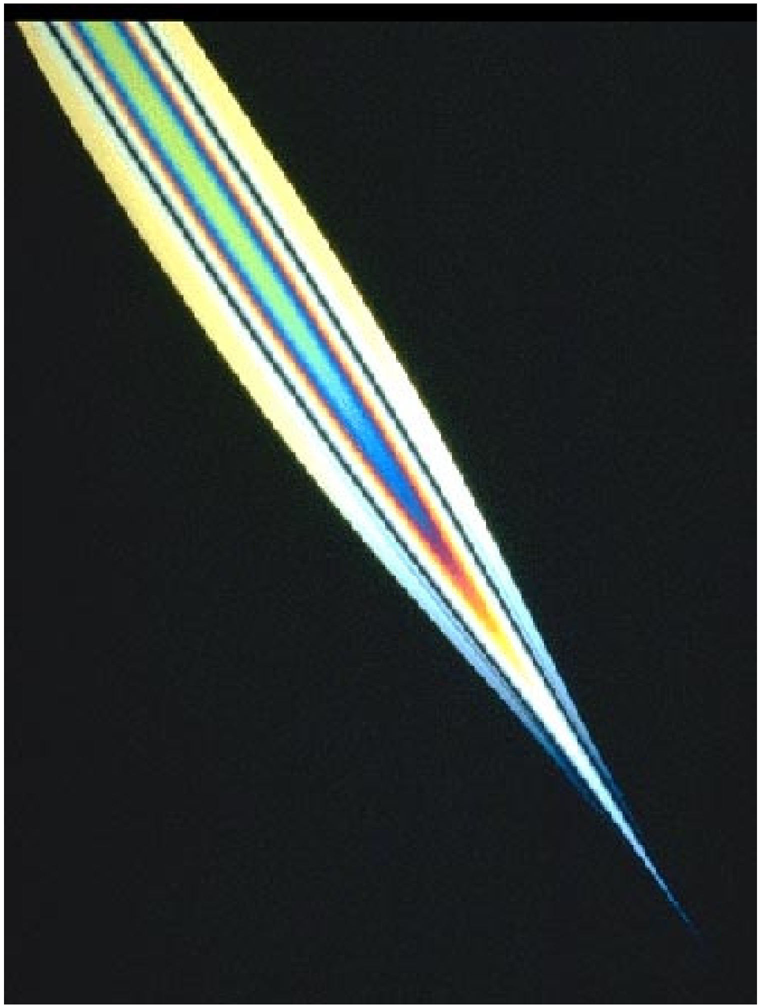
# How Fiber Optic is Fabricated.






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## How Fiber Optic is Made.



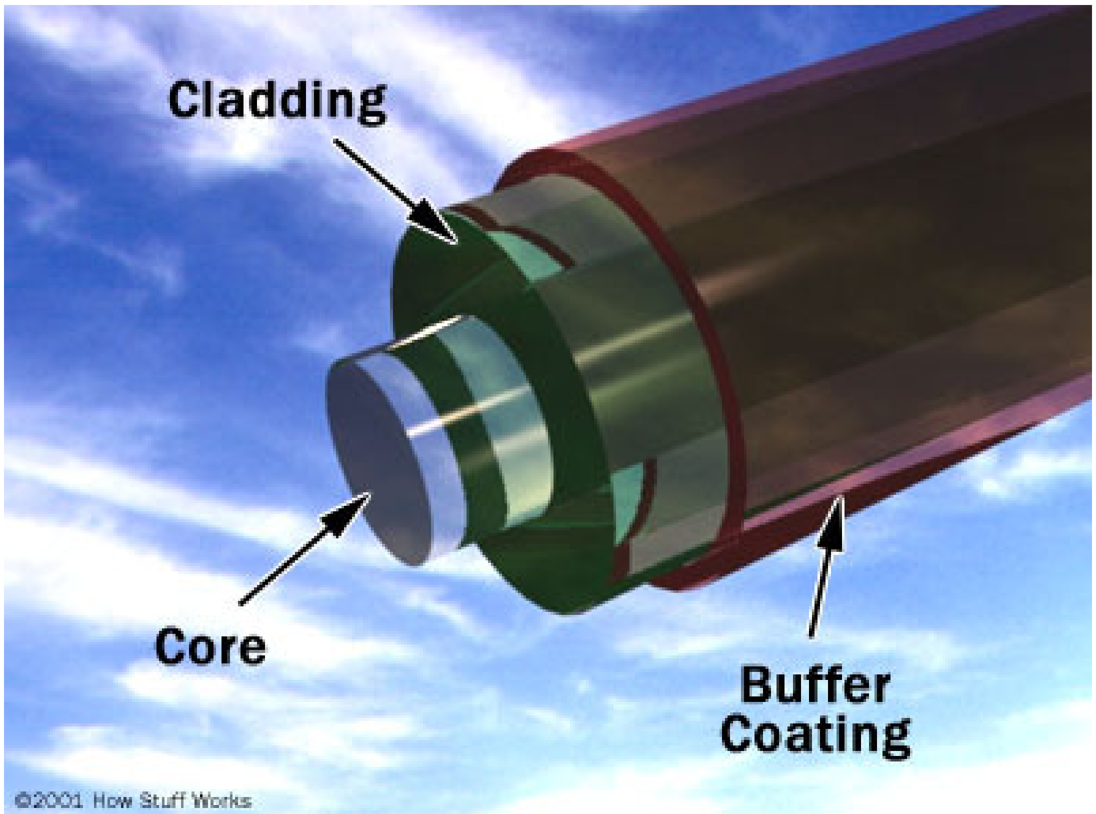
Optic PREFORM been melting into fiber optic.



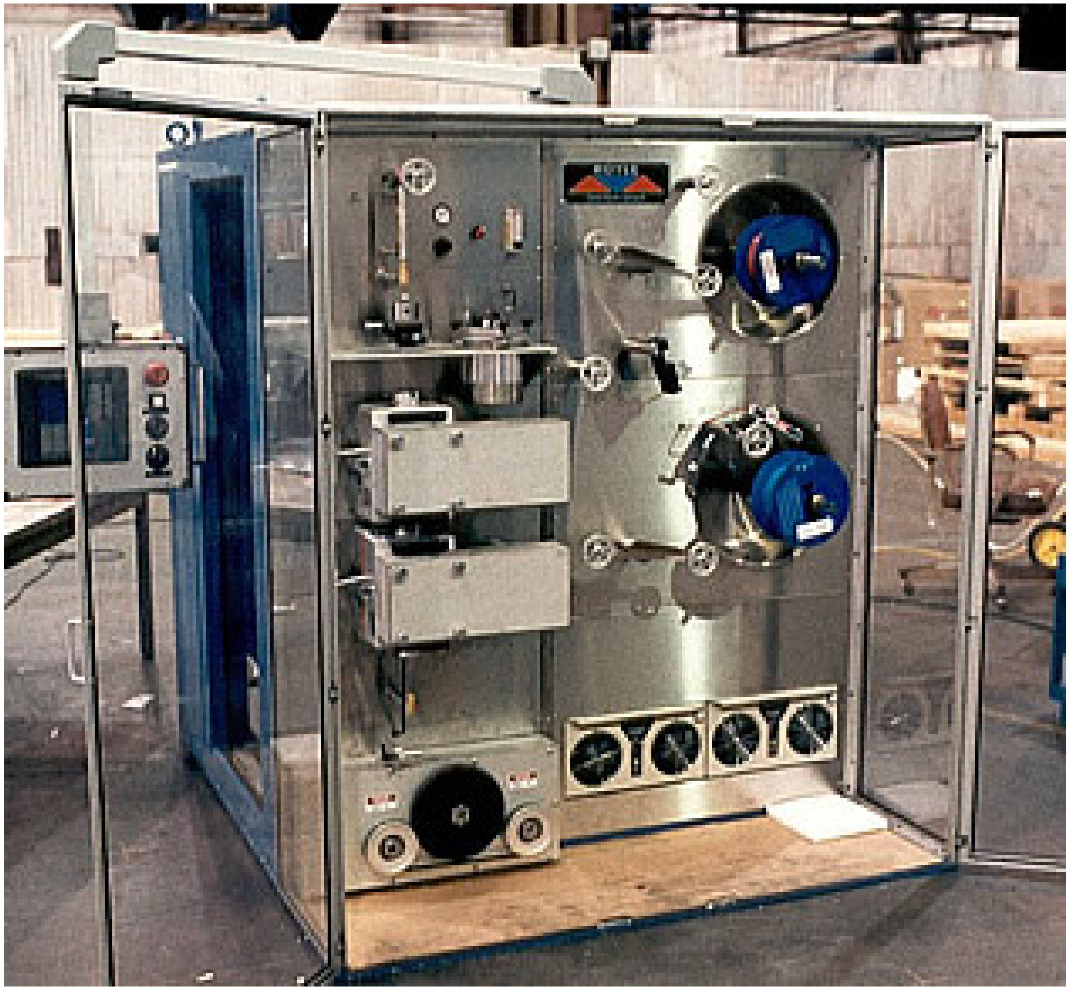
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# How Fiber Optic is Made.

**Below is a fiber which consist of the CORE " where light is been propagated, CLADDING " which keep the light inside the CORE" and BUFFER which is colour coated and permit the identification of the fiber.**

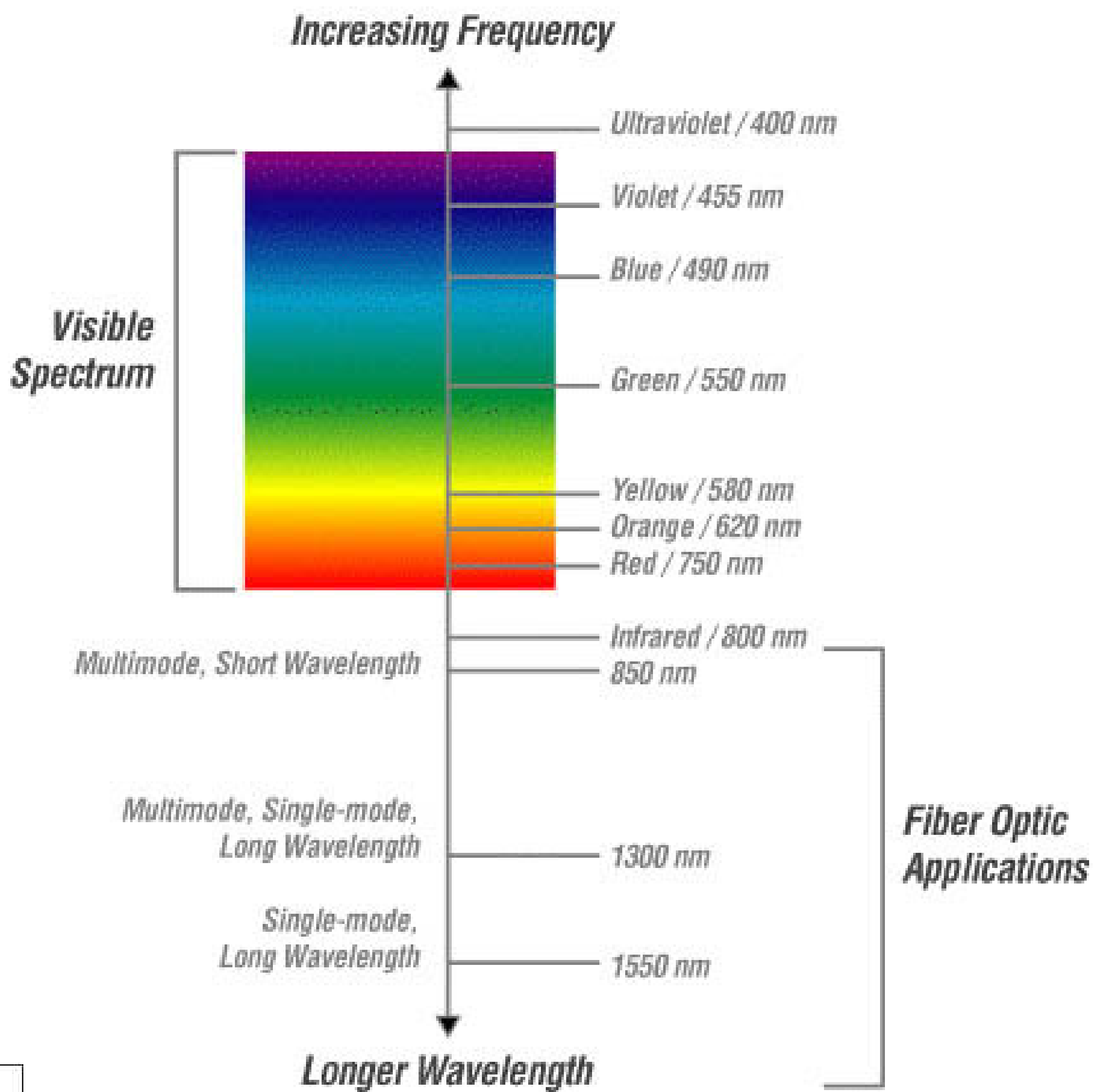


## How Fiber Optic is Made.



**Colour been added to the fiber optic for identification.**

# Fiber Optic Frequency range .




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# Advantages of Fiber Optic.

- **Low Optical Signal Loss -** Reduces or eliminates active devices in the outside plant.
- **High Optical Bandwidth -** Large quantity of information can be rapidly transmitted.
- **Does Not Produce, nor Is Affected by Electromagnetic Interference.**
- **Small and Light -** Easy to install, high duct efficiency.
- **Cost.**

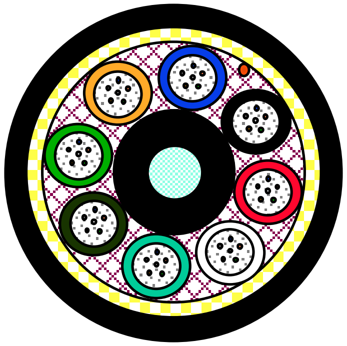
## Type of Communications with Fiber Optic.

**Two types of technologies exits in fiber optic;**

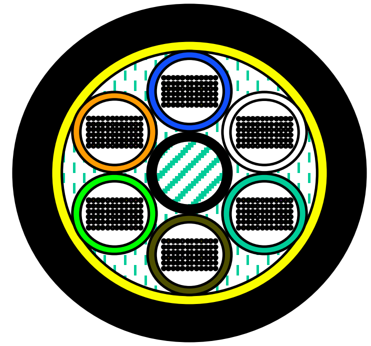
- **Multimode, where many paths of light are been transmitted.**
- **Singlemode where only one single light path is transmitted.**

- ***In HFC Broadband System, only Singlemode fiber optic is used.***

# Fiber Optic Cable.

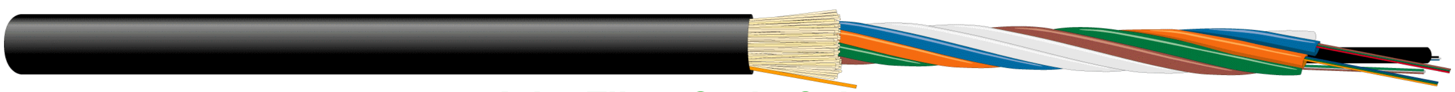


Loose tube fiber



Ribbon fiber

Fiber optic cable comes in many flavours, most common flavours, are losses tube fiber and ribbon fiber. These fiber cables can be armoured for duck placing or buried installation or just plain jacketed for aerial placing.



Arial Fiber Optic Cable

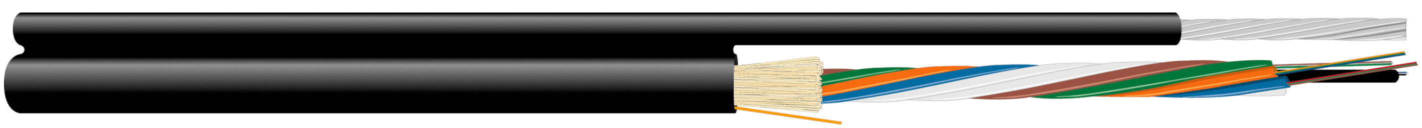
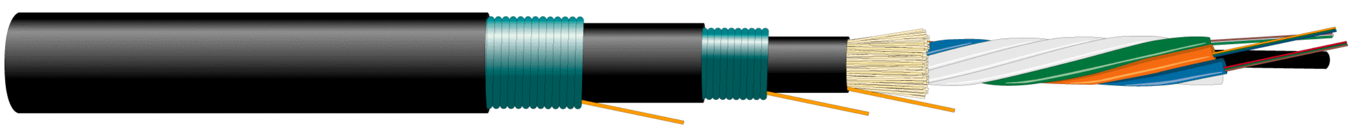


Figure 8 Fiber Optic Cable



Armoured Fiber Optic Cable

# Fiber Optic.

**The chart below shows the frequency and the signal loss of modern fiber optic.**

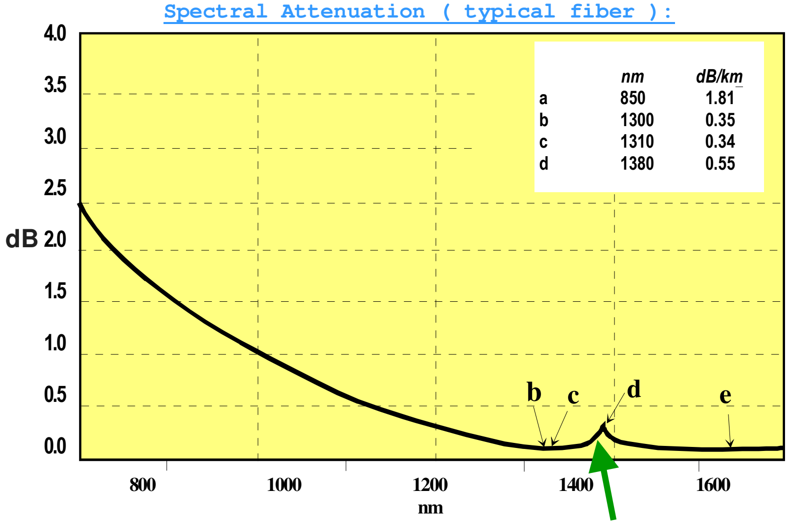
**•1310 nm = 0.33 dB per kilometre**

**•1550 nm = 0.19 dB per kilometre.**

## Performance Characteristics of single mode fiber optic.

Single-mode standard fiber optic

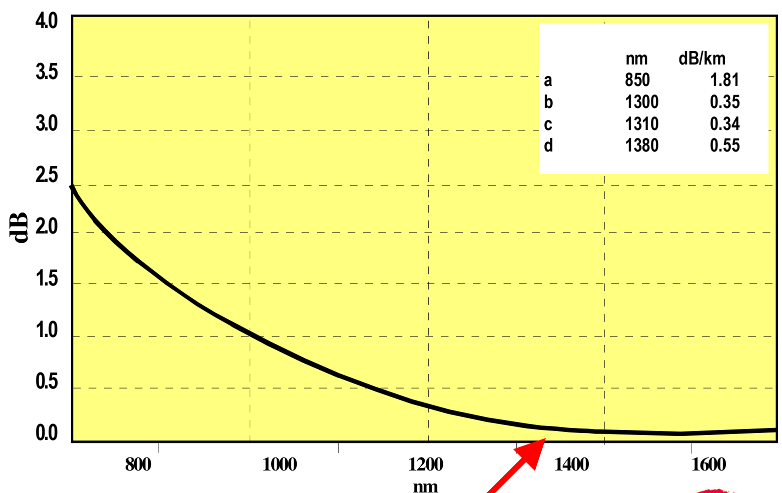
Spectral Attenuation ( typical fiber ):




**Moisture peak**

AllWave single-mode fiber optic

Spectral Attenuation ( AllWave fiber ):




**Moisture peak removed**

Lucent Technologies
Bell Labs Innovations

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## Building a Fiber Optic Link for a Broadband System.

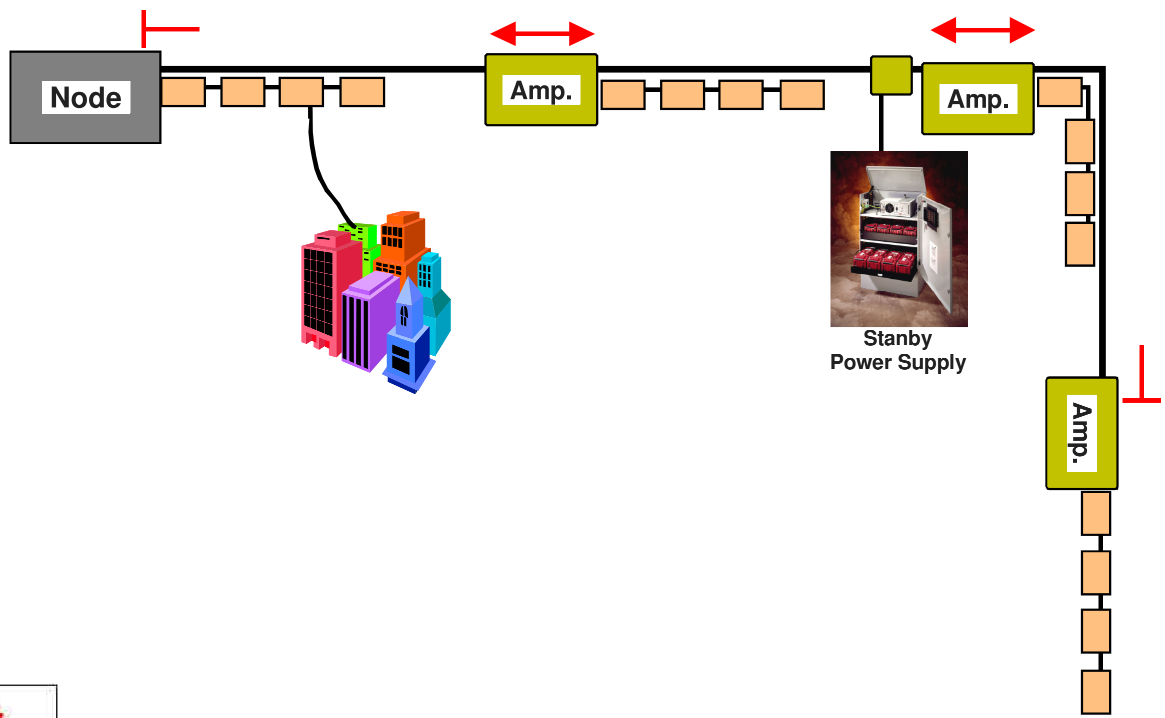
**Things to do before building a fiber optic link for a Broadband system;**

- Determine the number of customer each NODE will feed.
- The forward operating optical frequency; 1310 or 1550 nm.
- How many fiber optic to leave at each NODE, for future use.
- Will the optical transmitter feed one NODE or will we use the coupler / splitter technology to feed many NODE.
- The right optical input required at each NODE.
- How many return signal from NODE will be mixed at the headend.

## Building a Fiber Optic Link for a Broadband System.

• **Determining the number of customer the NODE will feed signal to.**

**Determining the number of customer per NODE is a very important function. Deciding on the wrong number of customer per NODE could mean another rebuilt in a near future. The number of subscribers been feed per NODE, can be any where from 50 to 1500. The return path usually determine the number of subscribers been feed per NODE. Cablemodem service or IP telephony usually requires a smaller amount of subscribers per NODE.**

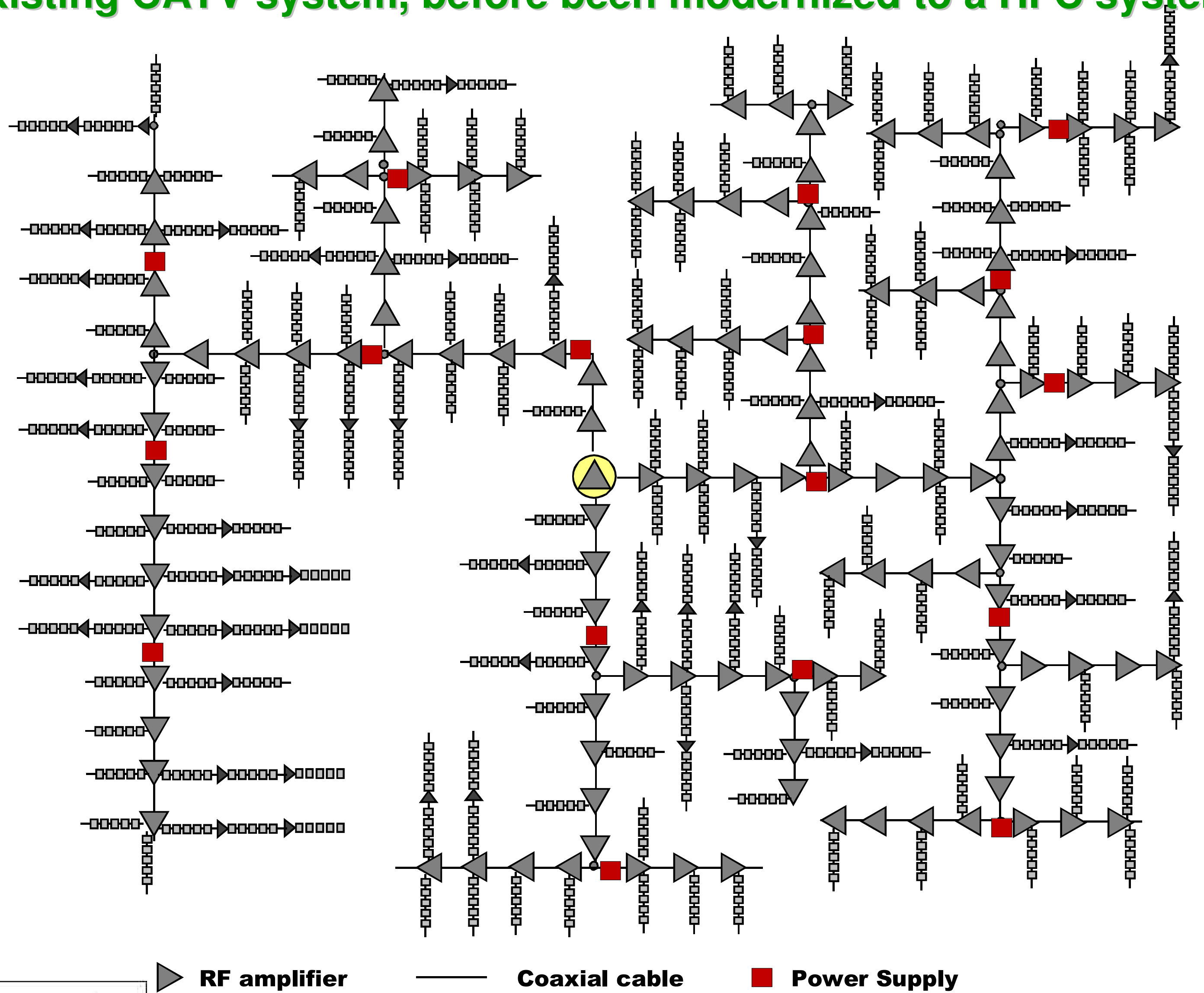





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# Determining the number of NODE required.

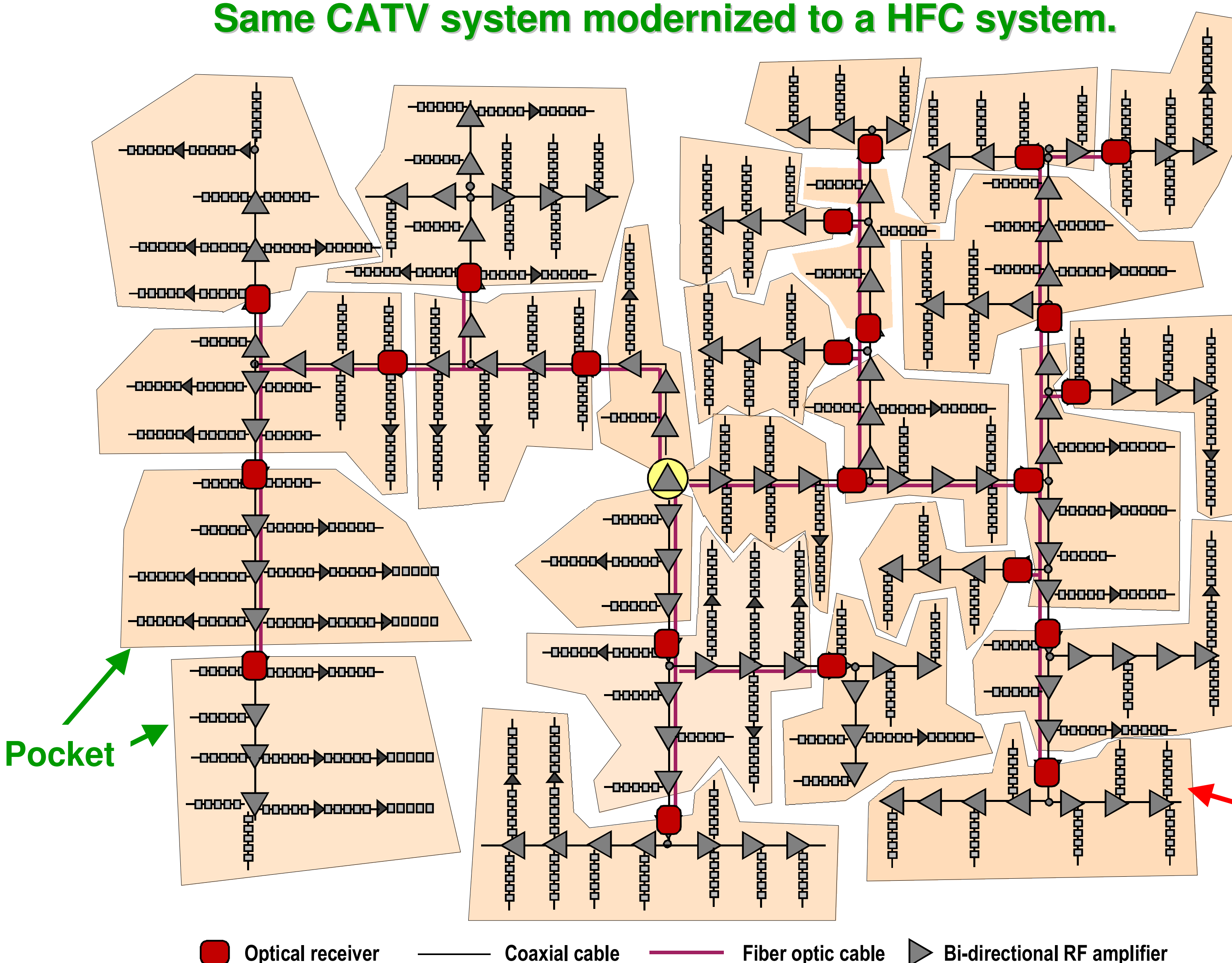
## Existing CATV system, before been modernized to a HFC system.




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# HFC system.

## Same CATV system modernized to a HFC system.





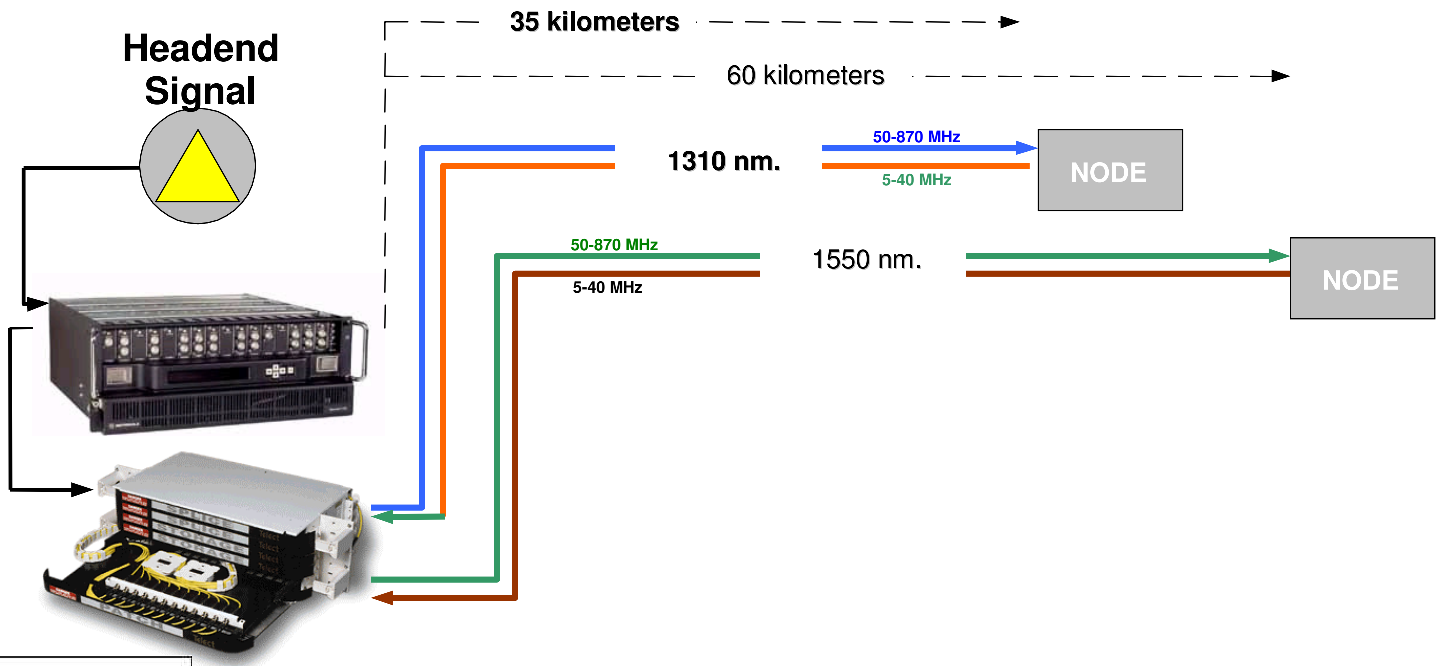

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## Building a Fiber Optic Link for a Broadband System.

- <u>The forward operating optical frequency; 1310 or 1550 nm</u>

**The maximum distance between a headend and a NODE operating at 1310 nm, is around 35 to 40 kilometres. This distance will also depend on the bandwidth of the system, 550, 750 or 870 MHz and the number of TV channel to be delivered.**

**With 1550 nm frequency and the use of EDFA (Erbium Doped Fiber Amplifier) a link can be as much as 100 kilometres from the HEADEND.**



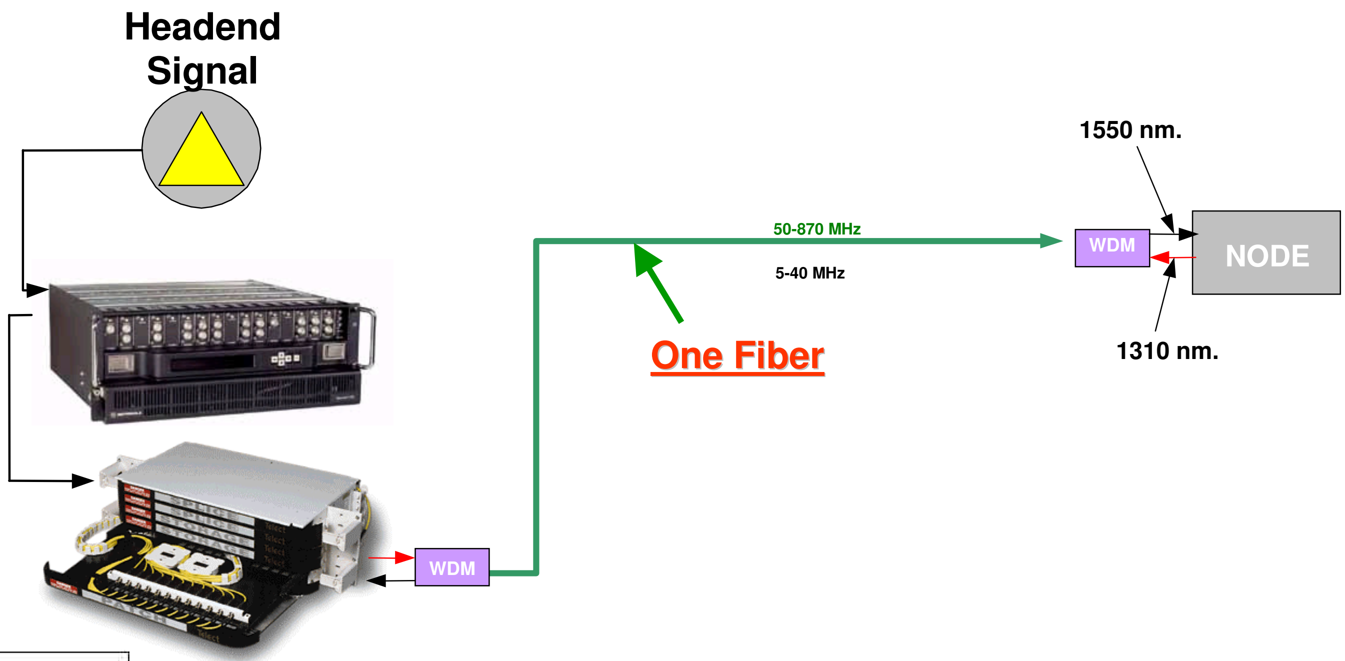

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# Building a Fiber Optic Link for a Broadband System.

•**How many fiber optic to leave at each NODE for future use.**

**Even if one fiber is enough to get a NODE working in both direction, two fiber are usually required. Not knowing what the future will required, many operator are leaving as much as 8 to 12 fiber per NODE.**

**Operating with one fiber per NODE, two frequencies 1310 and 1550 nm are required. A WDM (Wave Division Multiplexing) is required at each end, to permit both frequencies to work on the same fiber. This is sometime done, when not enough fiber were installed at the start of a Broadband System.**

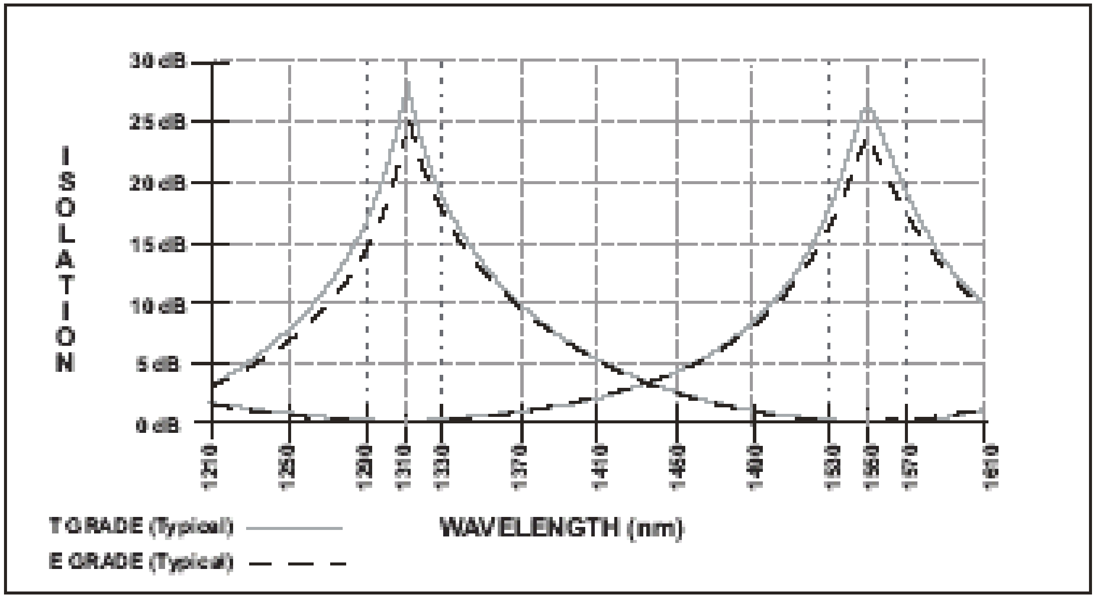


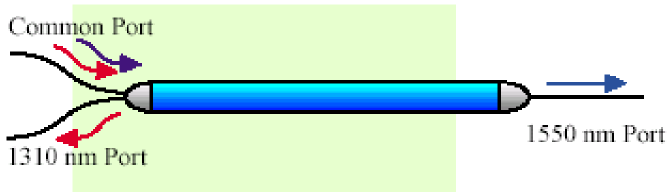



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# Description of a WDM.

## ISOLATION vs. WAVELENGTH



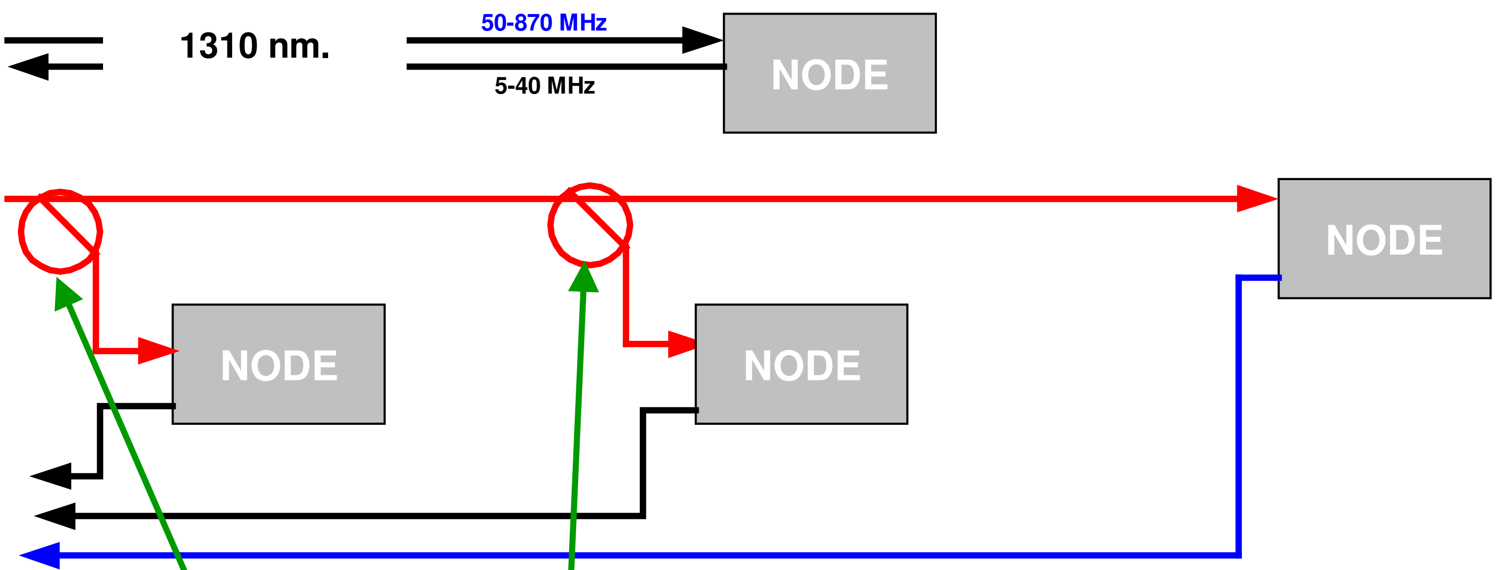




## OPTICAL/MECHANICAL PARAMETERS

| Grade | Wavelength | Passband | Directivity | Insertion Loss | Polarization Stability | Thermal Stability | Operational Temp. |
|---|---|---|---|---|---|---|---|
| T | 1310/1550 nm<br>1480/1550nm<br>980/1550 nm | ±20 nm | ≥55 dB (1x2)<br>≥65 dB (2x2) | ≤0.4 dB | ±0.1 dB<br>over all SOP | ±0.1 dB over<br>temperature range | -40°C to 85°C |
| E | 1310/1550 nm<br>1480/1550 nm<br>980/1550 nm | ±20 nm | ≥50 dB (1x2)<br>≥65 dB (2x2) | ≤0.6 dB | ±0.15 dB<br>over all SOP | ±0.1 dB over<br>temperature range | -40°C to 85°C |

## Building a Fiber Optic Link for a Broadband System.

**One optical transmitter can supply signal to one or many NODE. If one transmitter is feeding many NODE, the fiber link will require the use of optical splitter or coupler.**



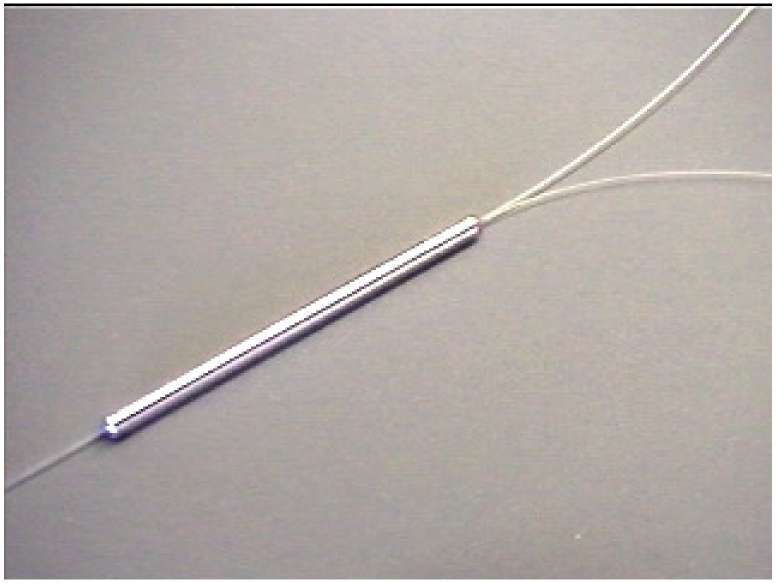

**You need to calculate the loss of each coupler, so each NODE will receive the right input.**



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## The loss in % and dB of the dual wave (1310 - 1550 nm) of optical splitter & coupler.

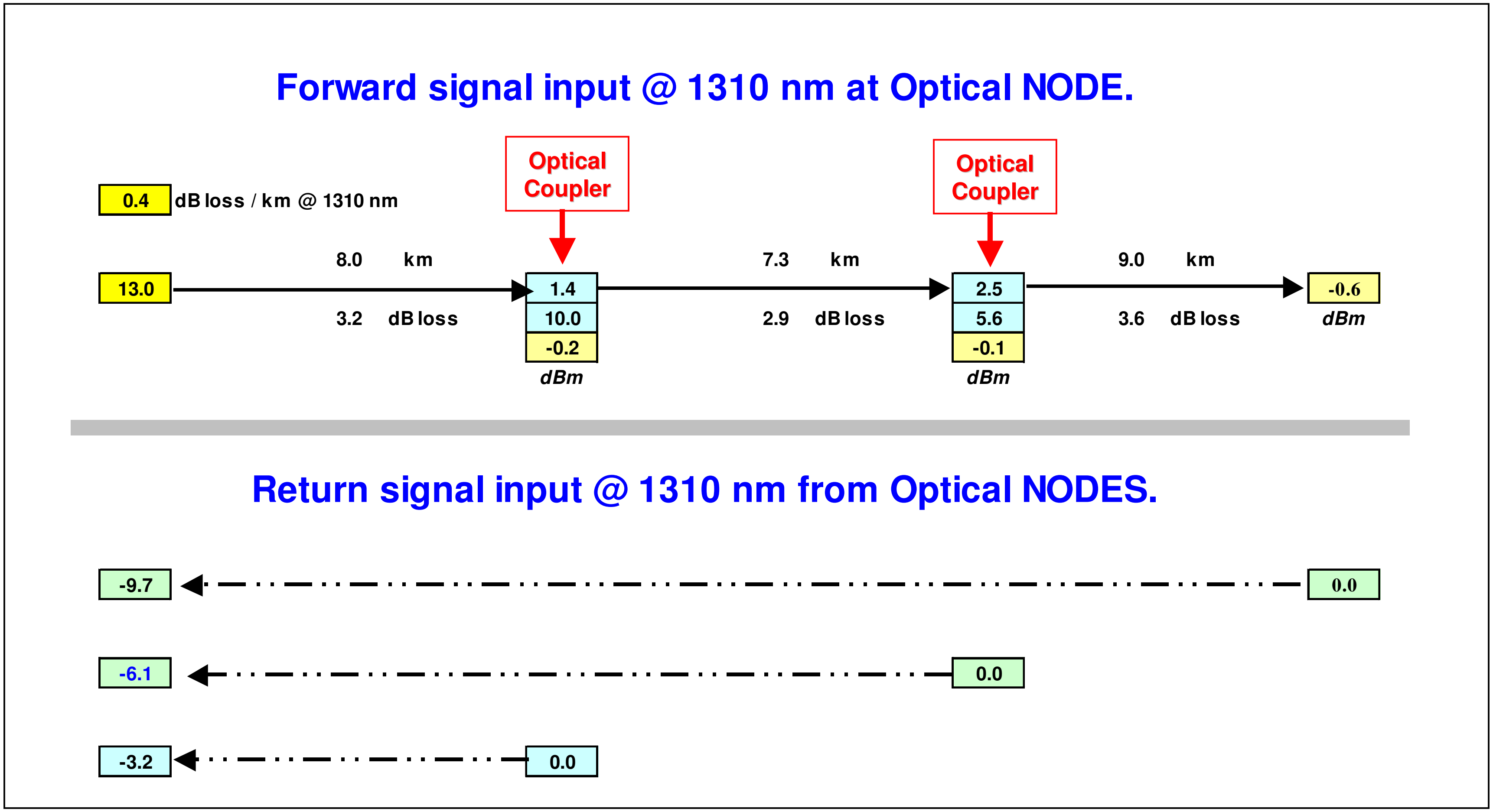
| | |
|---|---|
| 50 / 50 % | 3.6 / 3.6 dB |
| 55 / 45 % | 3.2 / 4.1 dB |
| 60 / 40 % | 2.7 / 4.7 dB |
| 65 / 35 % | 2.3 / 5.3 dB |
| 70 / 30 % | 2.2 / 5.7 dB |
| 75 / 25 % | 1.8 / 6.8 dB |
| 80 / 20 % | 1.3 / 7.8 dB |
| 85 / 15 % | 1.0 / 9.2 dB |
| 90 / 10 % | 0.8 / 11.2 dB |
| 95 / 5 % | 0.5 / 14.4 dB |



**In most cases, you will need to add the fusion splices to these loss.**

# Building a Fiber Optic Link for a Broadband System.

## Using 1 transmitter for 3 optical NODE using optical couplers.




**Notice here, that I am using 0.4 dB loss / km at 1310 nm, when the actual loss is 0.33 dB / km. By using this as the actual loss, I do not have to calculate the extra loss for connectors and fusion splicing in the optical link.**

## Building a Fiber Optic Link for a Broadband System.

- **The right optical power input required at each NODE.**

**In a modern system each NODE require an input of : –1.0 to +2.0 dBm. We should always try to hit the receiver at 0.0 dBm. With this level and modern DFB (Distributed Feed Back) laser, the NODE,s technical specification should be:**

**C/N: 52.00 dB for 77 channels in CW mode.**

**CTB: -65.00 dB for 77 channels in CW mode.**

**CSO: -63.00 dB for 77 channels in CW mode.**

**Reducing the number of carried channels from 77 to 40, will increase the Carrier to Noise specification by 3.0 dB, but will not better the CTB and CSO specification.**

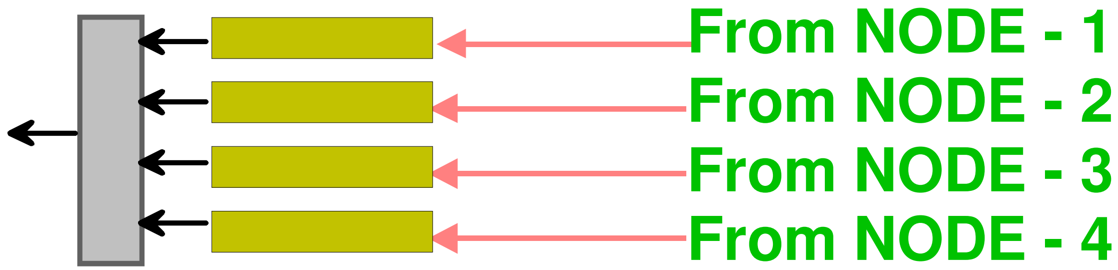
**Every dB away from 0.0 dBm input, will increase or decrease the C/N by one dB. Then a –1.0 dBm input will give 52.00 dB C/N and a +2.0 dBm will give a 55.00 dB C/N.**

**We should never hit a NODE with more than +2.0 dBm input. Optical input signal above +2.0 dBm will either shorten the receiving photo diode's life or will get the NODE to go into distortion.**

# Building a Fiber Optic Link for a Broadband System.

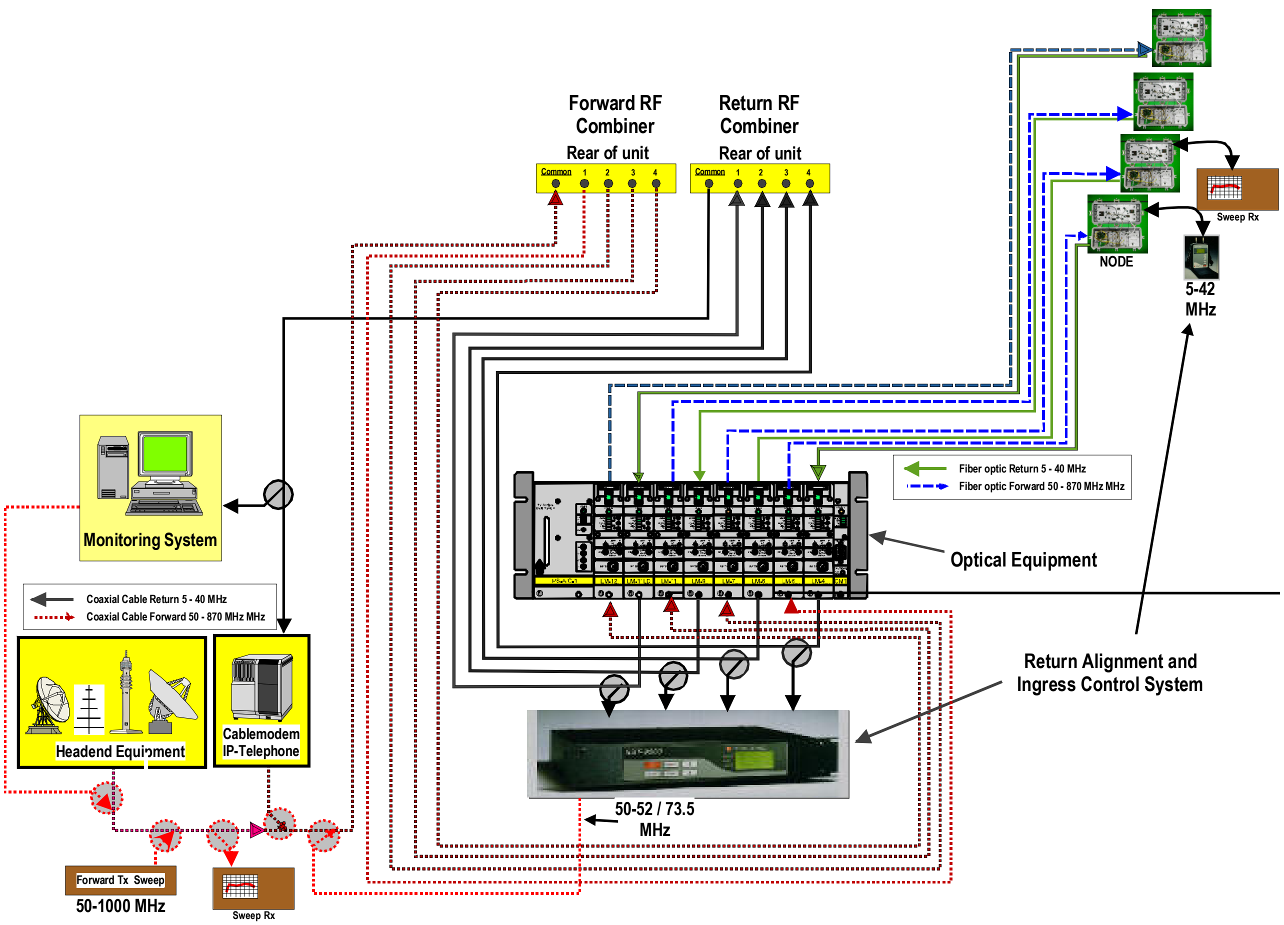
## The right number of return signal from NODE;

**Ideally every NODE should have it own return sent directly to the CMTS. Because of cost and to-day need, the industry is now presently mixing four (4) return signal from NODE per combining network.**



# Building a Fiber Optic Link for a Broadband System.

## Broadband Combining Network






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## Fiber Optic Cable.

**We will comes back to the technology fiber optic later on, in the seminar.**

# TEST!

- Name two types of signal a coaxial cable can carry?

____________________________________________________

- What is the impedance of coaxial cable used in a HFC system?

____________________________________________________

- Name the two types of coaxial cable used for a HFC system in North America?

____________________________________________________

- What is the maximum and minimum temperature coaxial cable are spec at?

____________________________________________________

- What type of AC wave comes out of a power supply used in a HFC system?

____________________________________________________

- Name two types of passives equipment used in a HFC system?

____________________________________________________

- How many types of multitap can we used in a HFC system?

____________________________________________________

# The end of this seminar.